Power prices and the impacts of fluctuating renewable generation on the operation of power markets

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Power prices and the impacts of fluctuating renewable generation on the operation of power markets

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Power prices and the impacts of fluctuating renewable generation

AGENDA

Background – Why is fluctuating/intermittent generation an issue in Denmark

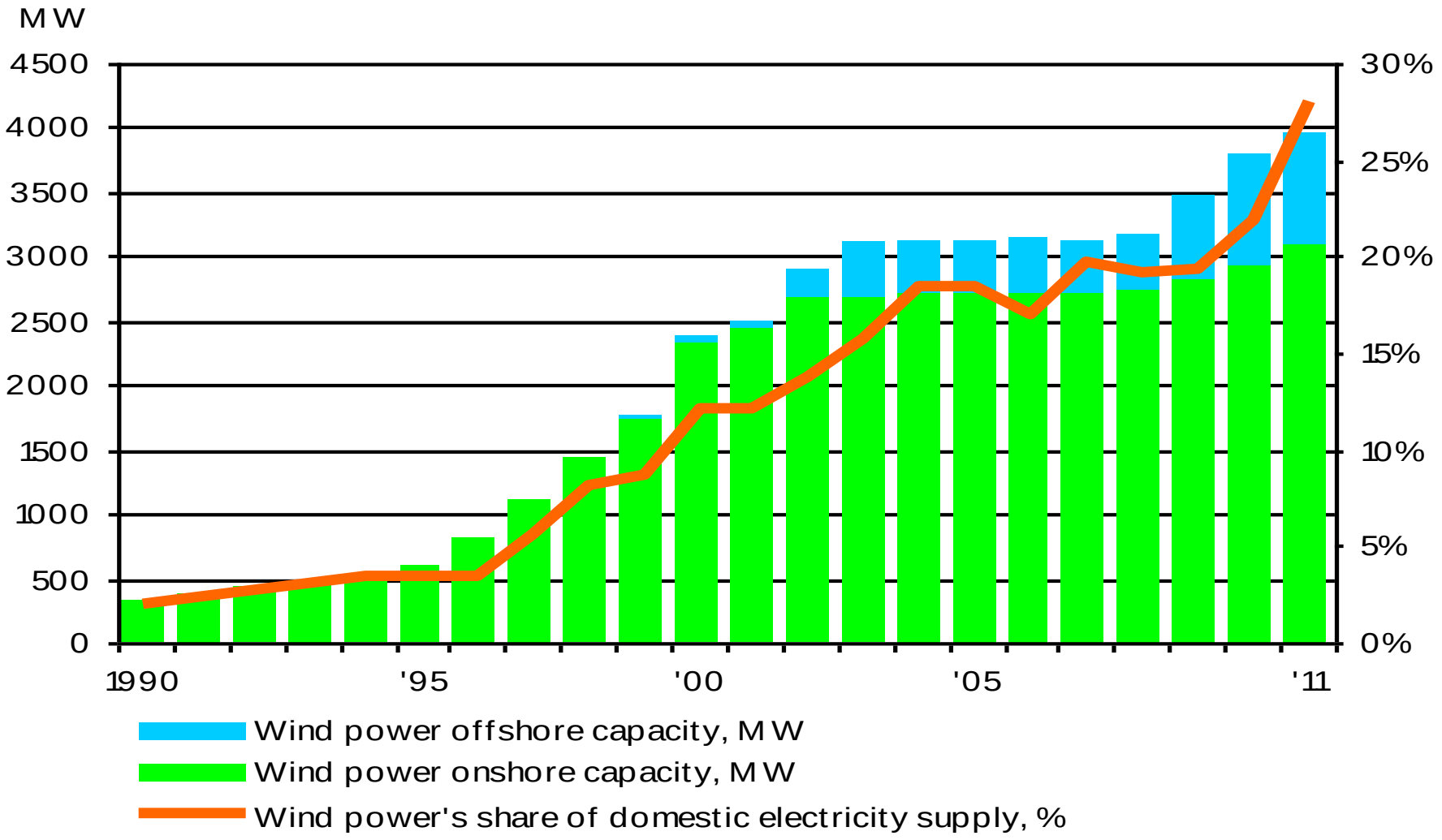
Short term effects on markets

- Short term marginal costs
- Day ahead power markets
- Average prices
- Price volatility
- Renewable generator revenues
- Interaction with other technologies

Long term effects on markets and investment incentives

- Support distort the market investment signals?
- The challenge: Does lower market price mean that more capacity is **not** needed?
- Negative prices - yes

Development of wind power in Denmark and its effect on power prices

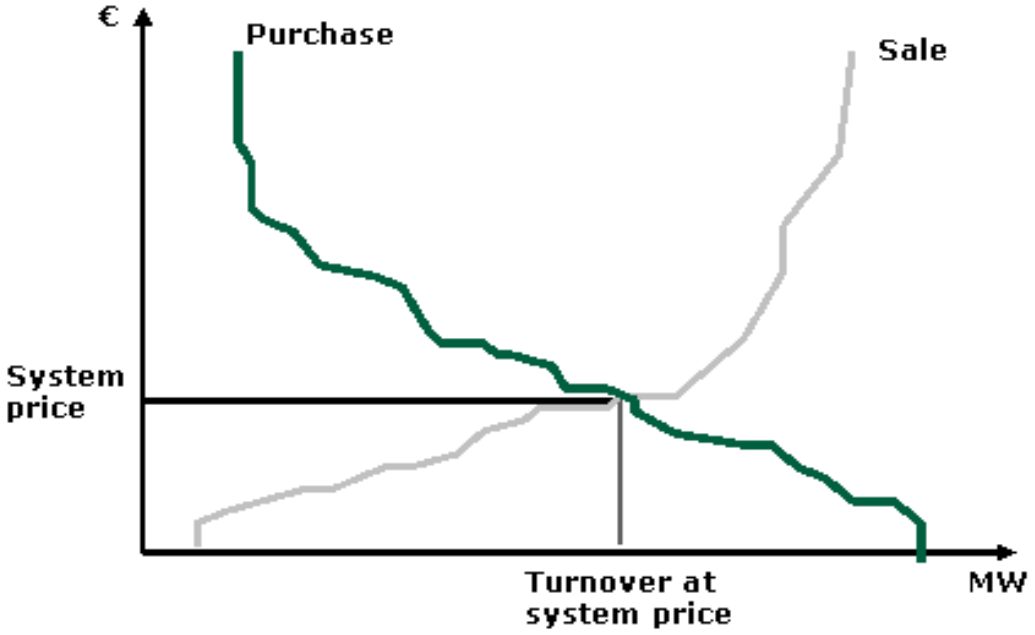


Denmark have a politically agreed target for reaching a fossil fuel free energy consumption in the year 2050

Wind energy is relatively cheap and will be a main contributor to this development
Target for 2020 is 50% of total electricity

Electricity markets: standard supply and demand

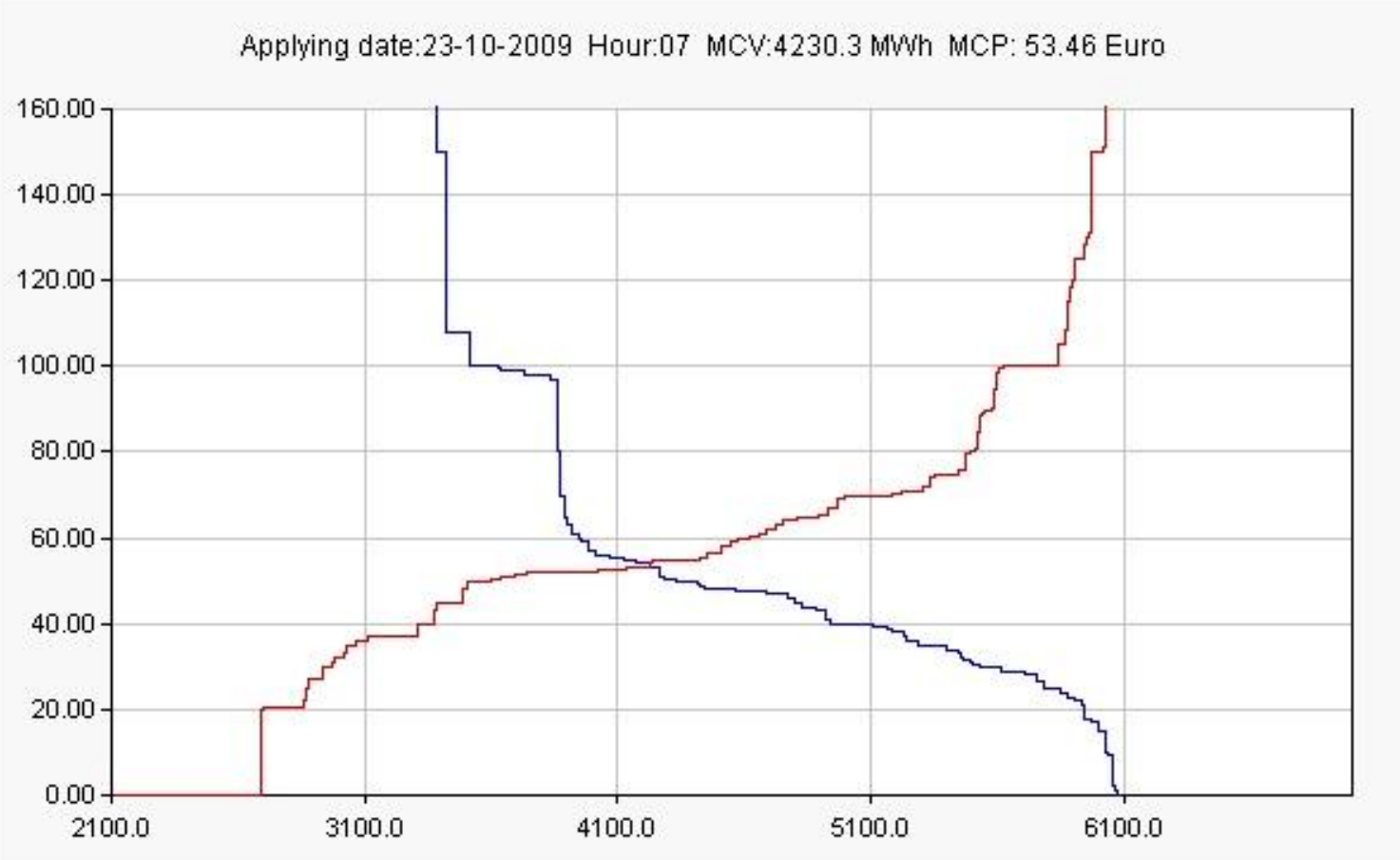
- Day ahead markets: 24 periods of 1 hour from 12 midnight the same day to 12 midnight the following day
- Buyers and sellers bid *stepped curves* based on their short term marginal costs
- A marketplace clears the market at 12 noon and instruct generators to follow the corresponding generation plan the following day



Nordpool homepage/NASDAQ

AGGREGATED CURVES

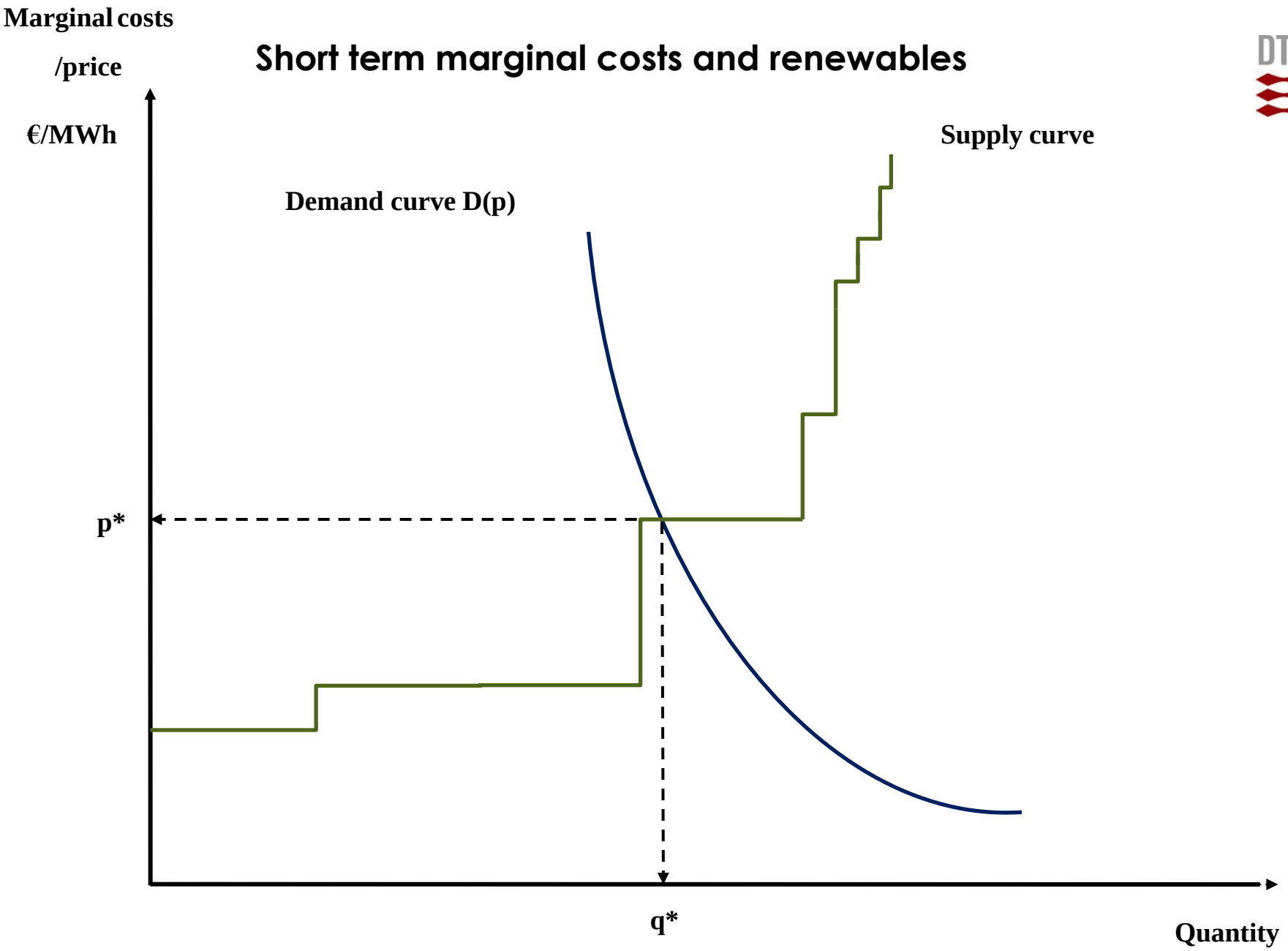
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 Zoom



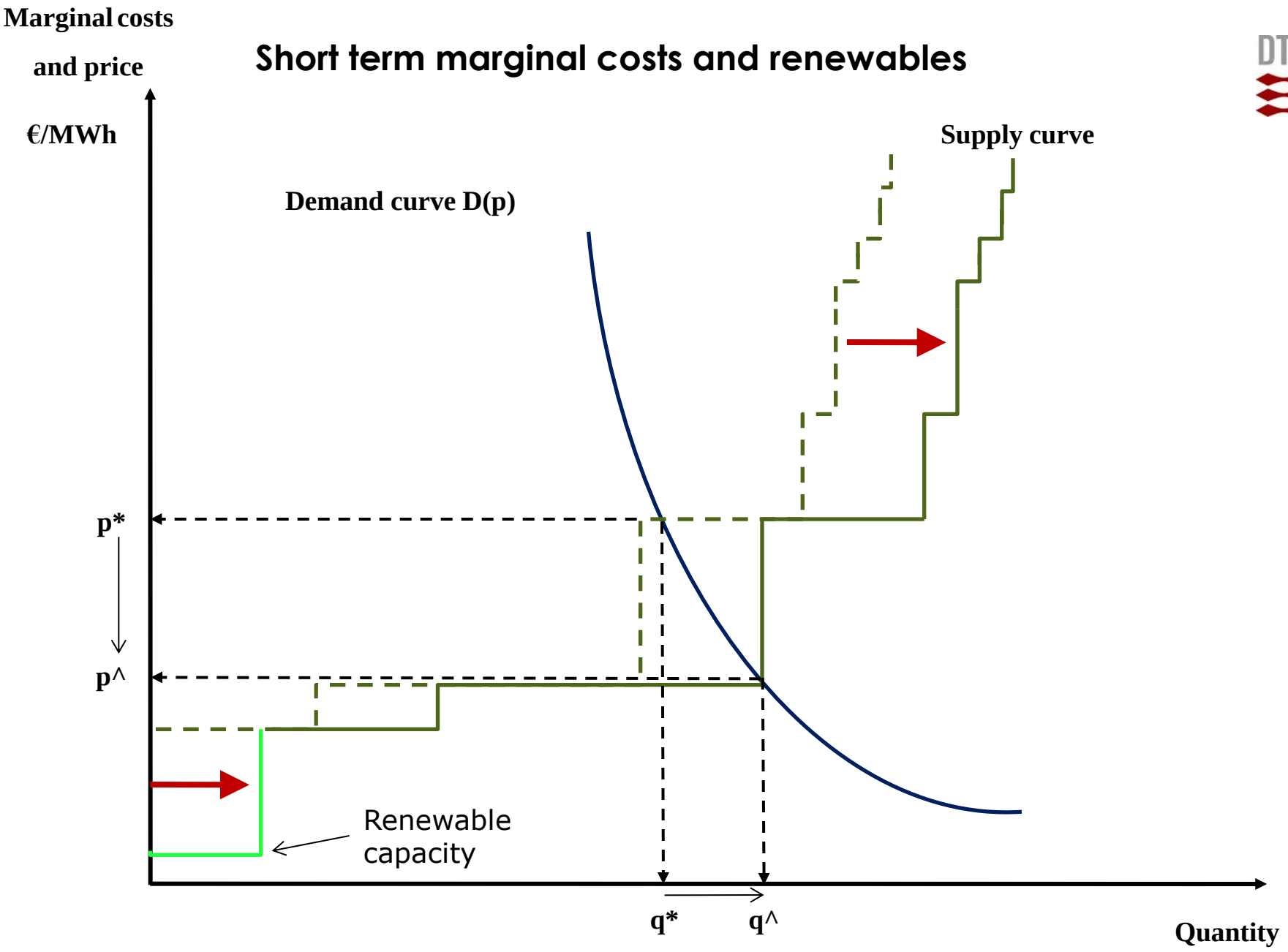
Short term marginal costs determine power price

- The supply curve in day ahead market is reflecting the short term marginal costs – the additional fuel cost per additionally produced MWh
- Generation technologies differ with regard to the mix of variable and fixed costs
- Fluctuating renewable generation has *very low* short term marginal costs
- Fluctuating generation forms the *lower left part of the supply curve*
- Variation in generation from renewables will thus shift the entire supply curve

Short term marginal costs and renewables

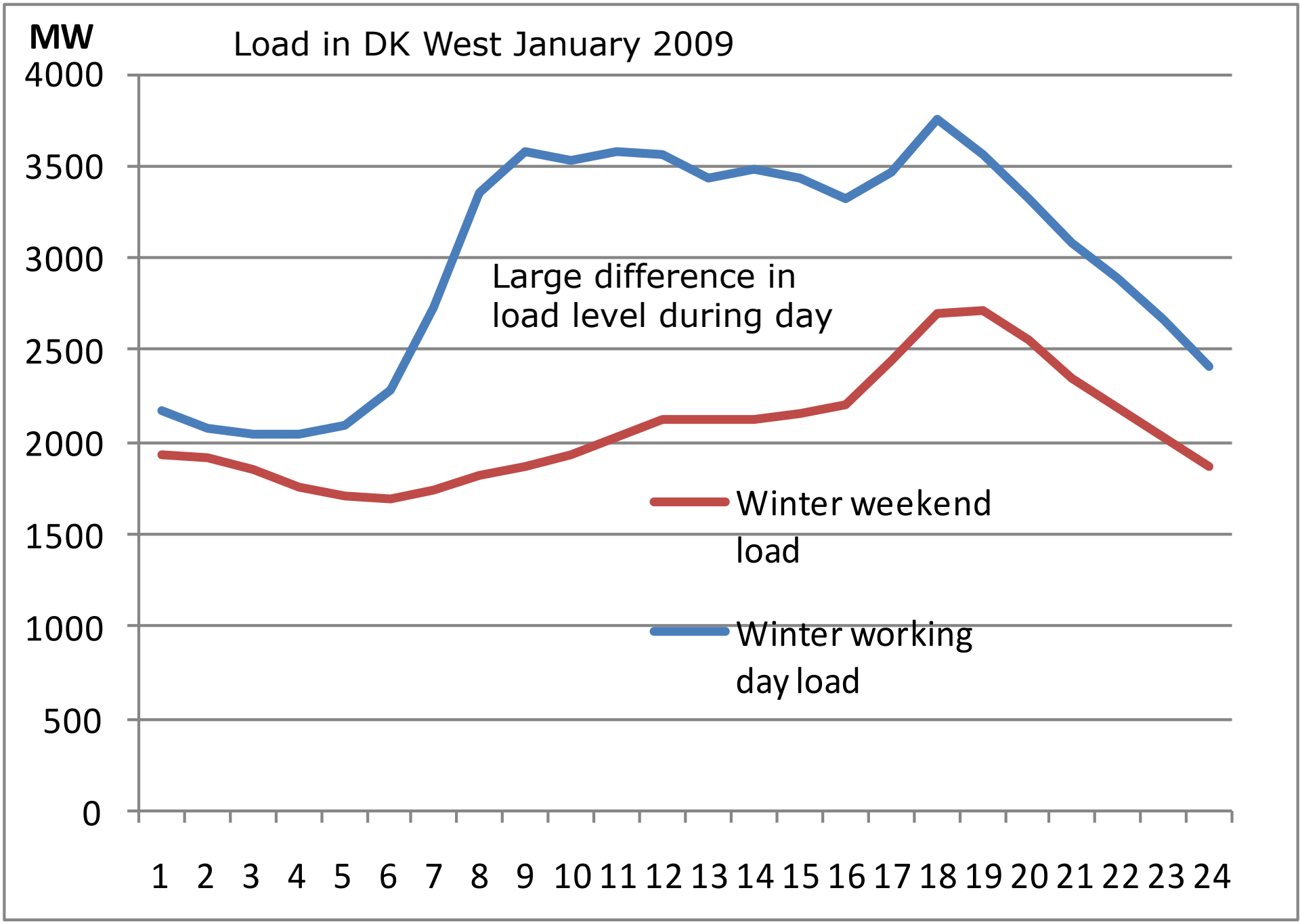


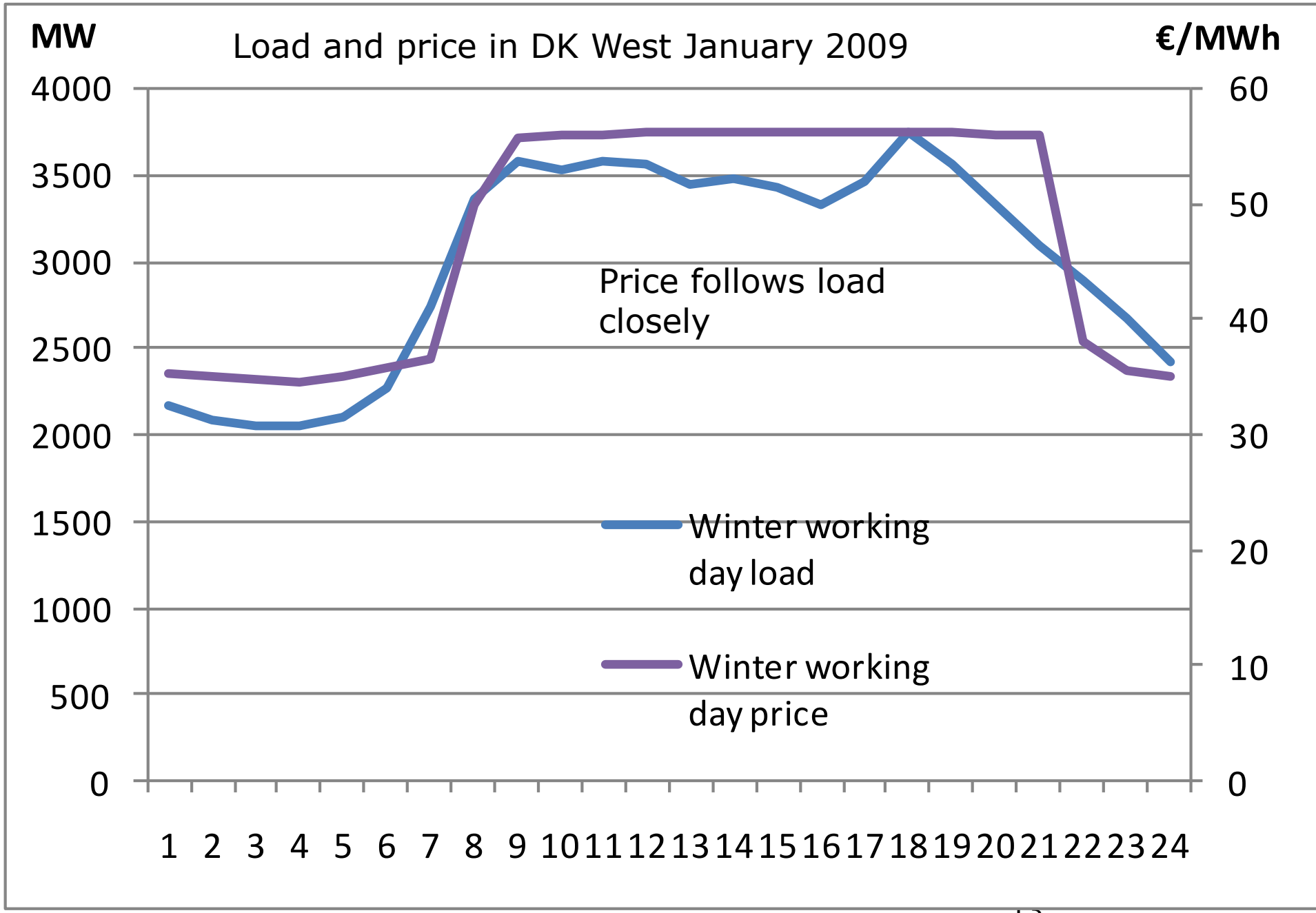
Short term marginal costs and renewables

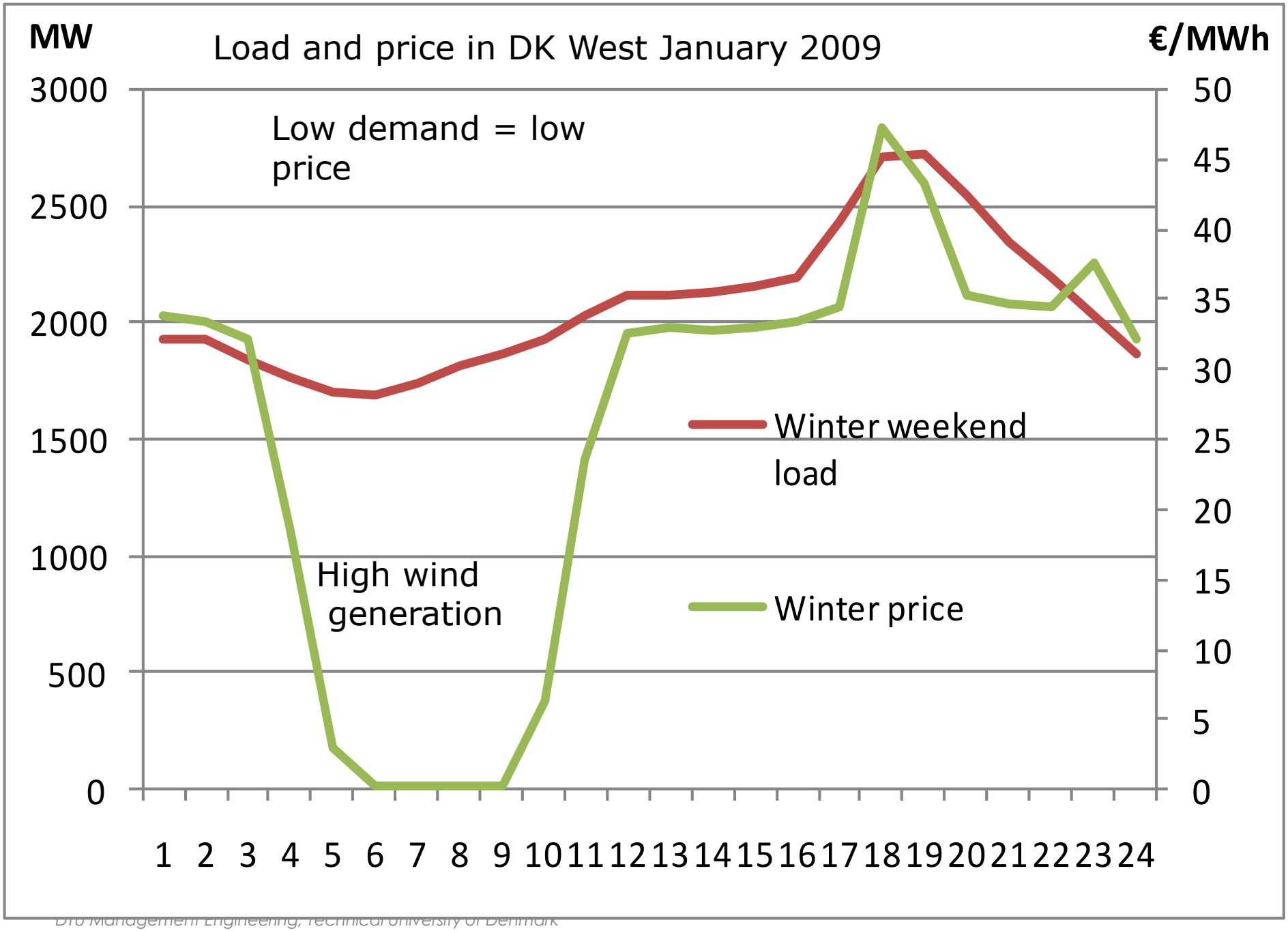


Adding renewable capacity and the short term price effect

- Average wholesale power price is reduced
- Price is reduced the most when demand is high (peak load) and the least when demand is low
- The effect is the same as when adding other low variable cost generation. Base load technologies with low marginal cost would also shift the supply curve to the right.
- The relative effect for consumer price is not as great, since the network costs and all the taxes are added to the wholesale price


MW
Load in DK West January 2009
4000
3500
3000
2500
2000
1500
1000
500
0
Large difference in load level during day
Winter weekend load
Winter working day load
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


MW
Load and price in DK West January 2009
€/MWh
4000
3500
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
Price follows load closely
Winter working day load
Winter working day price
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24


MW
Load and price in DK West January 2009
€/MWh
3000
2500
2000
1500
1000
500
0
50
45
40
35
30
25
20
15
10
5
0
Low demand = low price
High wind generation
Winter weekend load
Winter price
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

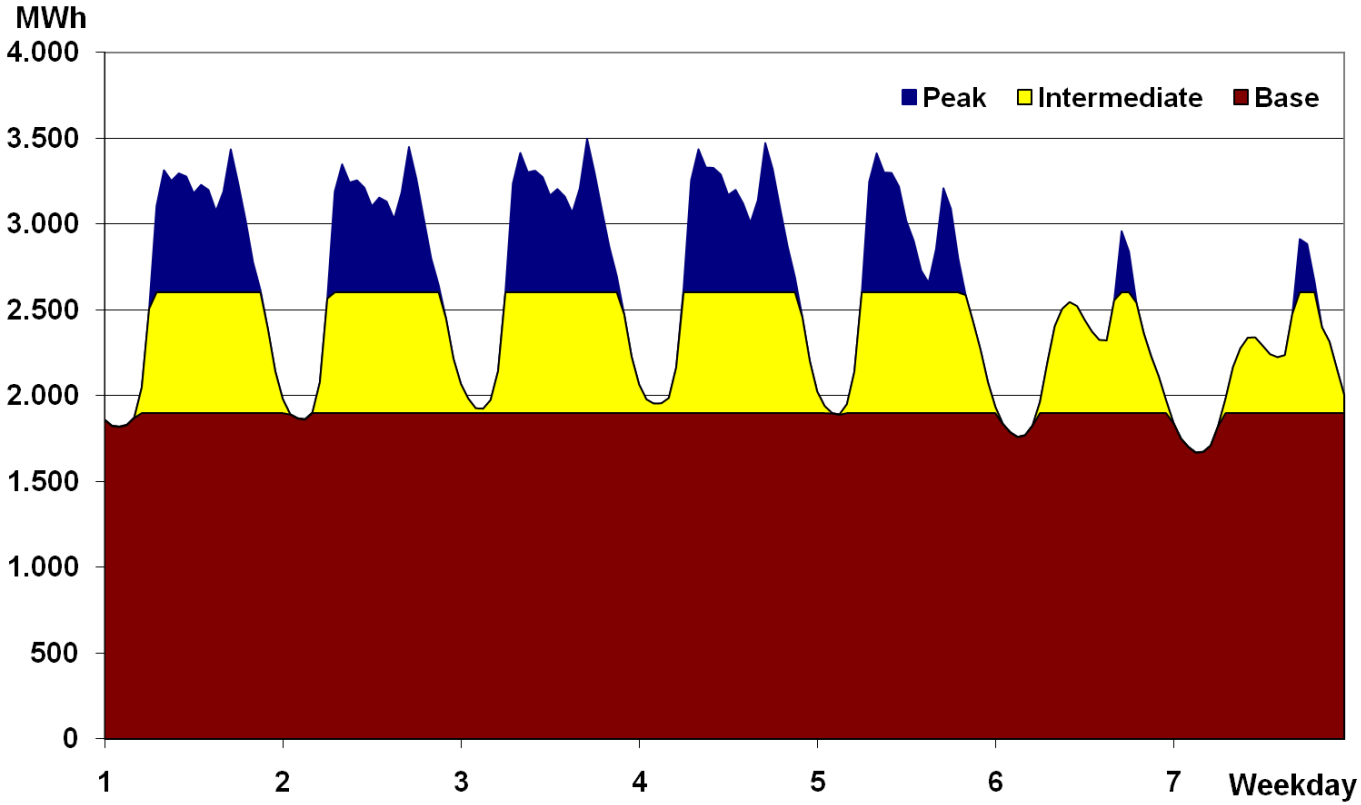
Price effect and volatility effect depends on demand variation and composition of power system

- Intermittent generation will affect prices most in systems with few flexible generation resources – nuclear, baseload coal etc.
- Intermittent generation will affect prices most if demand variation is large
- Price effect is high if short term demand flexibility (elasticity) is low
- Intermittent generation and interaction with very flexible hydropower systems is an ideal situation as the price effect will be less here
- Example: Danish wind and Norwegian hydropower

The price effect and the volume effect has an impact on all generation technologies

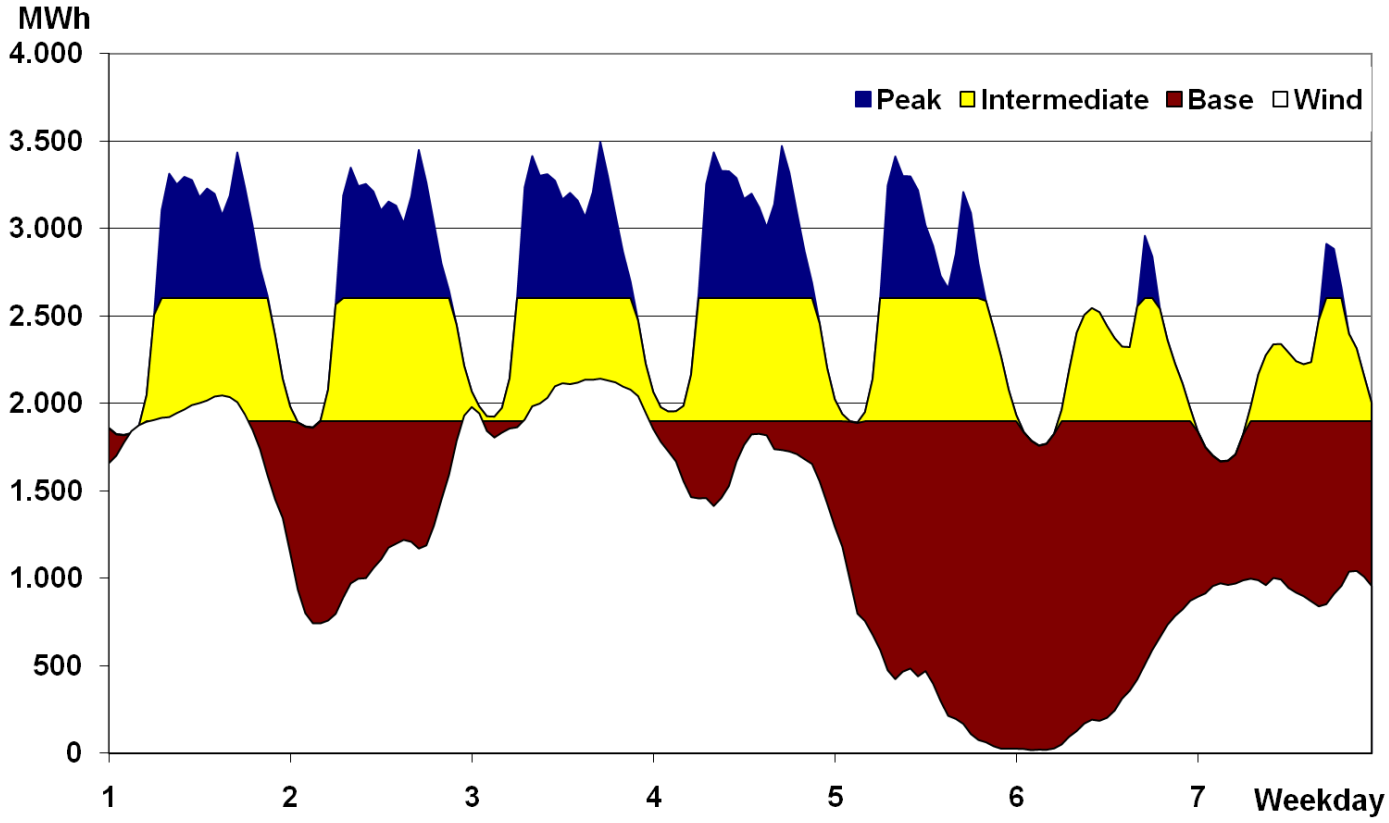
Electricity markets: Variation of hourly demand and technologies to cover demand

- traditional: separation into base, peak and intermediate generation
- illustrative example: DK West figures

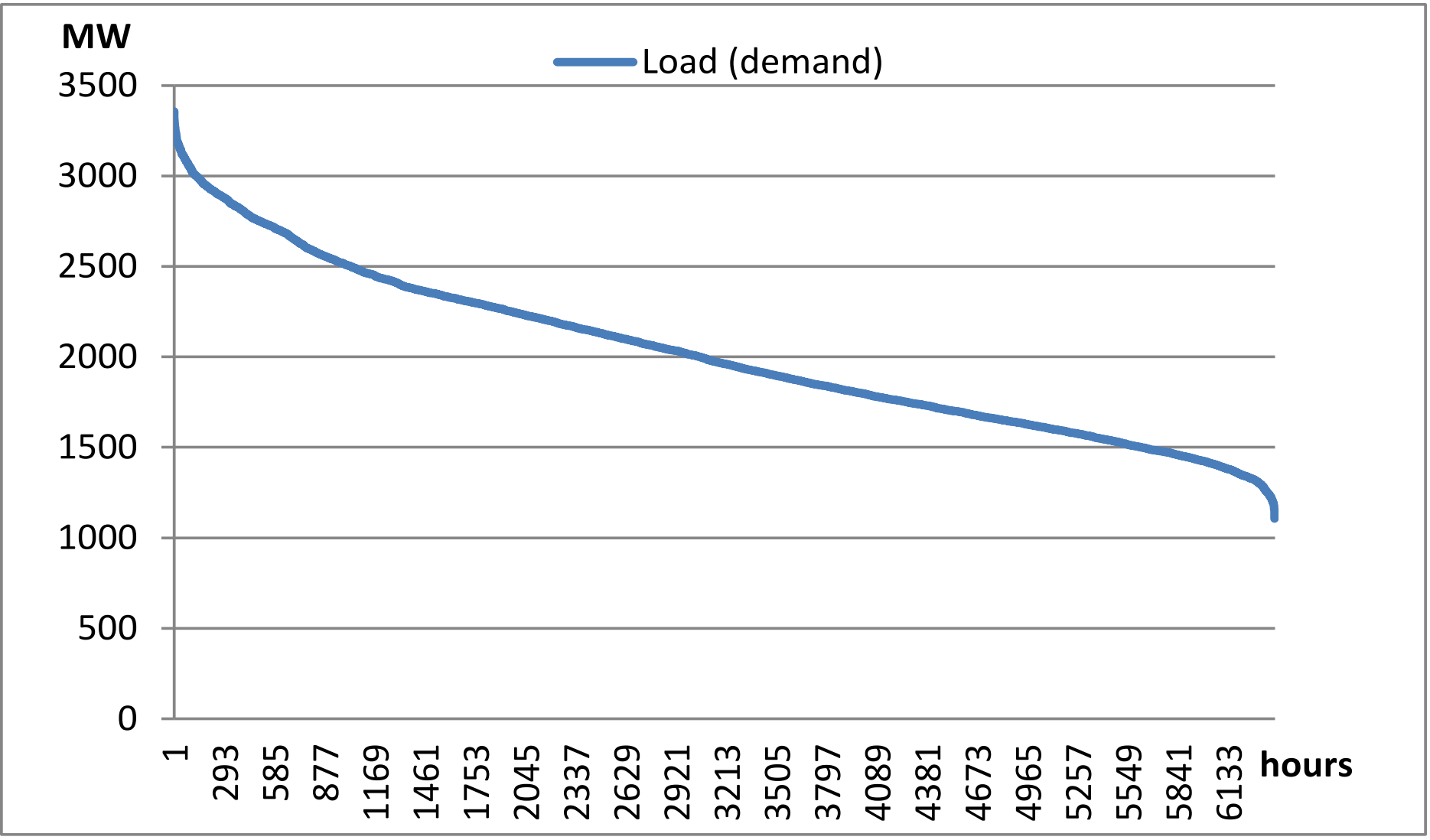


Electricity markets: Covering demand when intermittent generation added

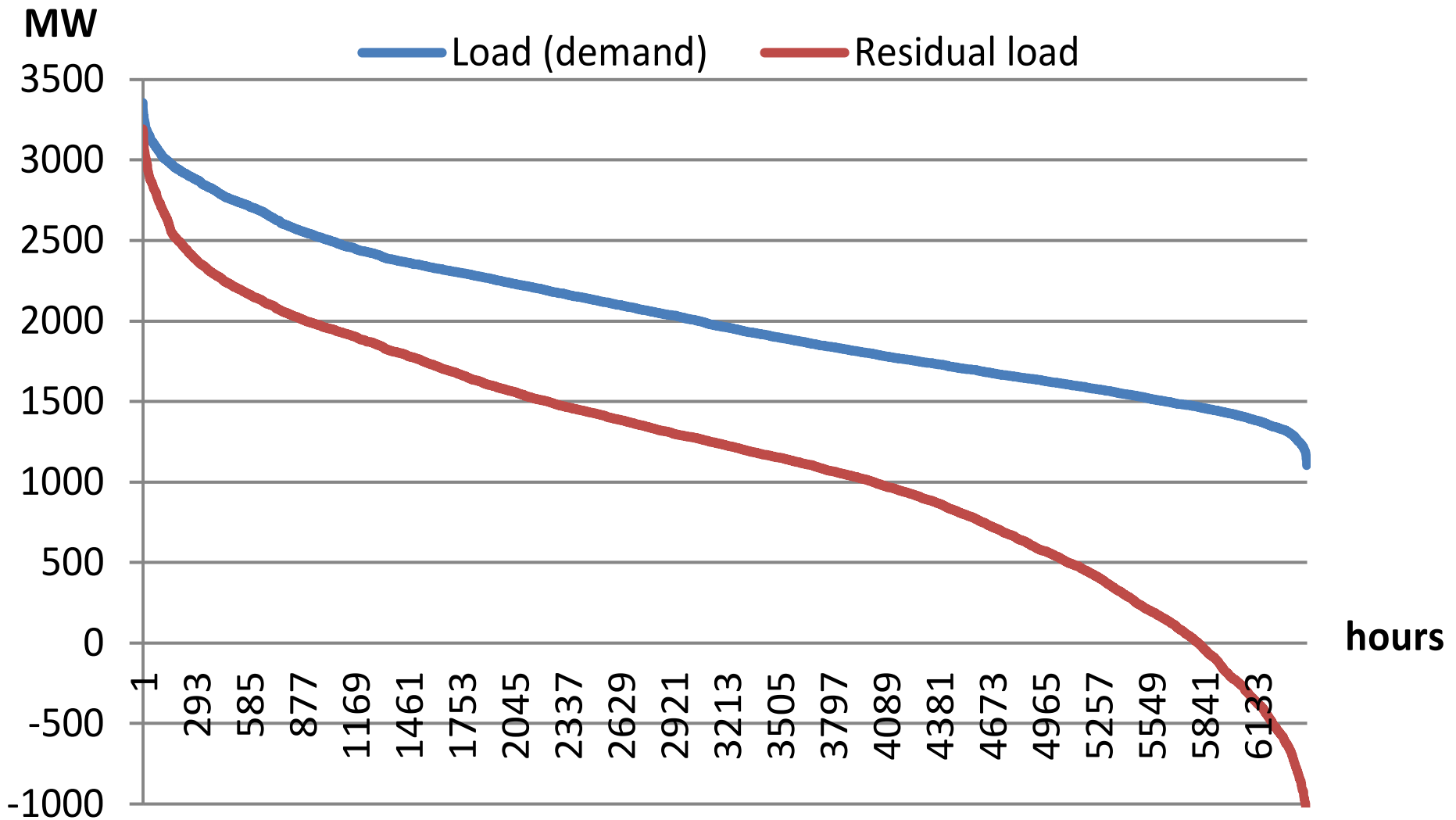
- now: fluctuating renewables
- illustrative example: Denmark-West, 2nd week 2005



Load duration curve Denmark West January-September 2013



Subtracting the wind generation Denmark West January-September 2013



Electricity price and renewable generator revenues

- Renewable generators receive support
  - feed-in tariffs
  - premiums
  - green certificates
  - investment grants or tax credits

So why does prices matter for renewables?

- First
  - premiums create some market dependence
  - green certificates imply high market price dependence
  - feed-in given as fixed term (15 years) support and afterwards 100% market!
- Secondly
  - Most utilities portfolios include intermittent generation and conventional generation
  - Theirs and competitors investment in intermittent generation will influence the price patterns of power markets and their total revenues

Annual revenue effects for generators

- For the average generator lower prices are unattractive
- For the peak plants this is even less attractive as peak prices are reduced the most and they have the major part of revenue from these hours
- **For intermittent generators as wind** only those with premium support or past support experience lower prices and as they have relatively larger share of generation at low price hours they already receive a lower revenue per generated MWh than other generators
- These wind generators have a disadvantage to controllable generation as their output is negatively correlated with prices high output at low price hours

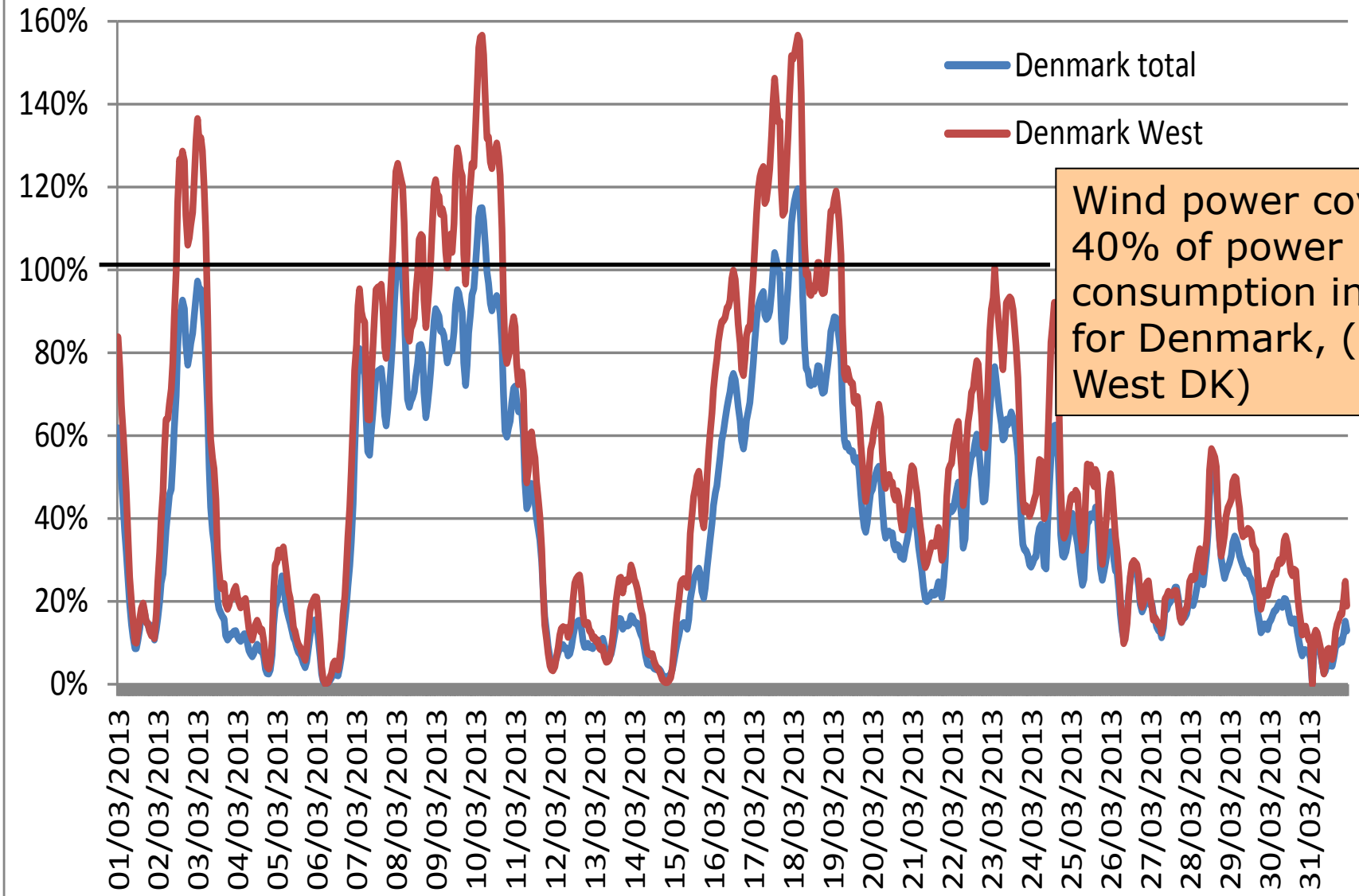
Wind generator revenue

Table 1 Wind generators market based revenues in the Western Denmark price area

	Area Price €/MWh (direct average of hours)	Wind average price €/MWh	Difference €/MWh	Wind price relative to market	Wind generation (GWh)	Potential loss mill. €
2006	44.19	40.54	3.64	92%	4614	16.8
2007	32.40	28.66	3.74	88%	5562	20.8
2008	56.42	51.20	5.22	91%	5190	27.1

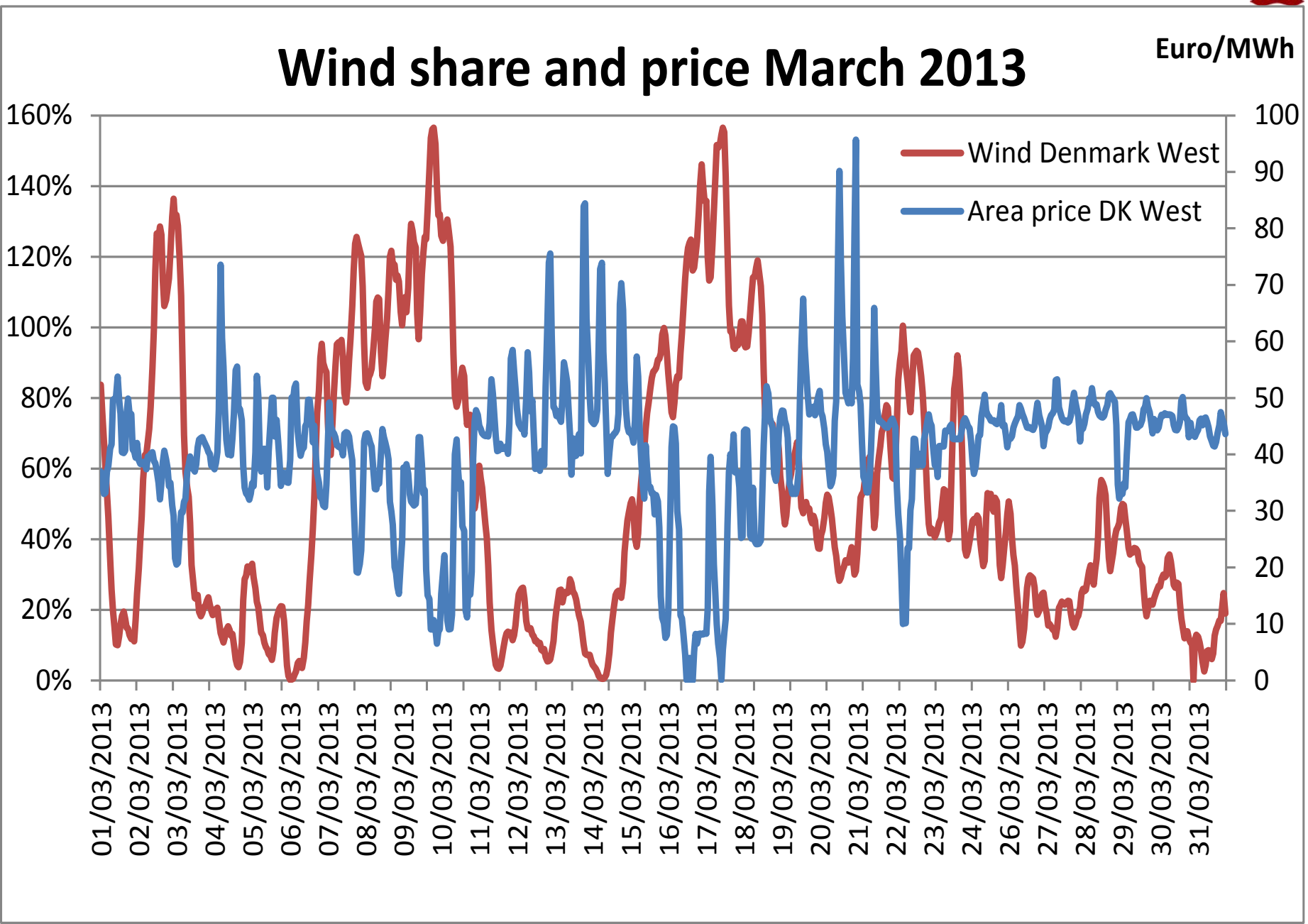
How much wind does Denmark have now and which price effect?

Wind share of consumption March 2013



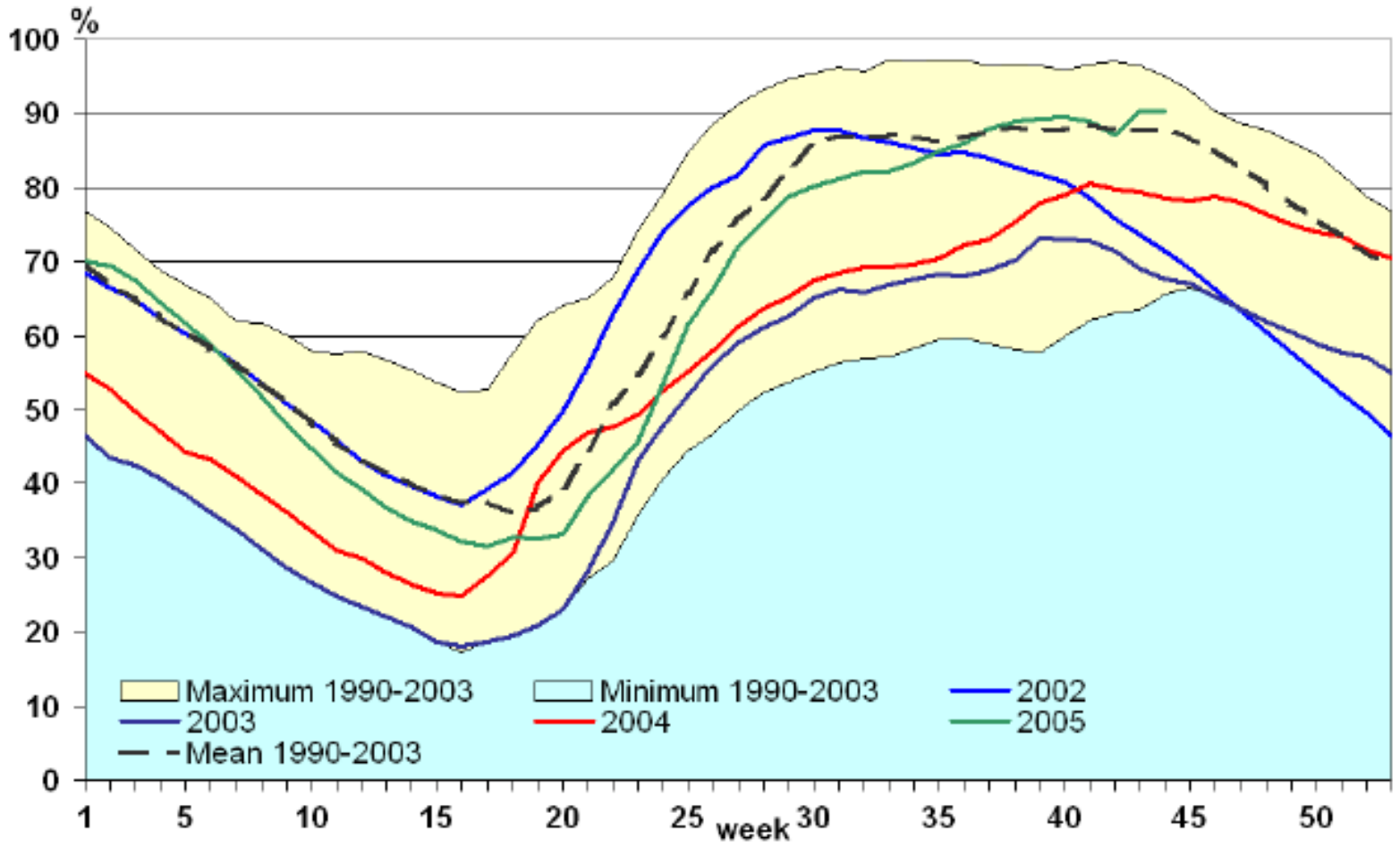
Wind power covered 40% of power consumption in March for Denmark, (53% in West DK)

Power price is negatively correlated with generation



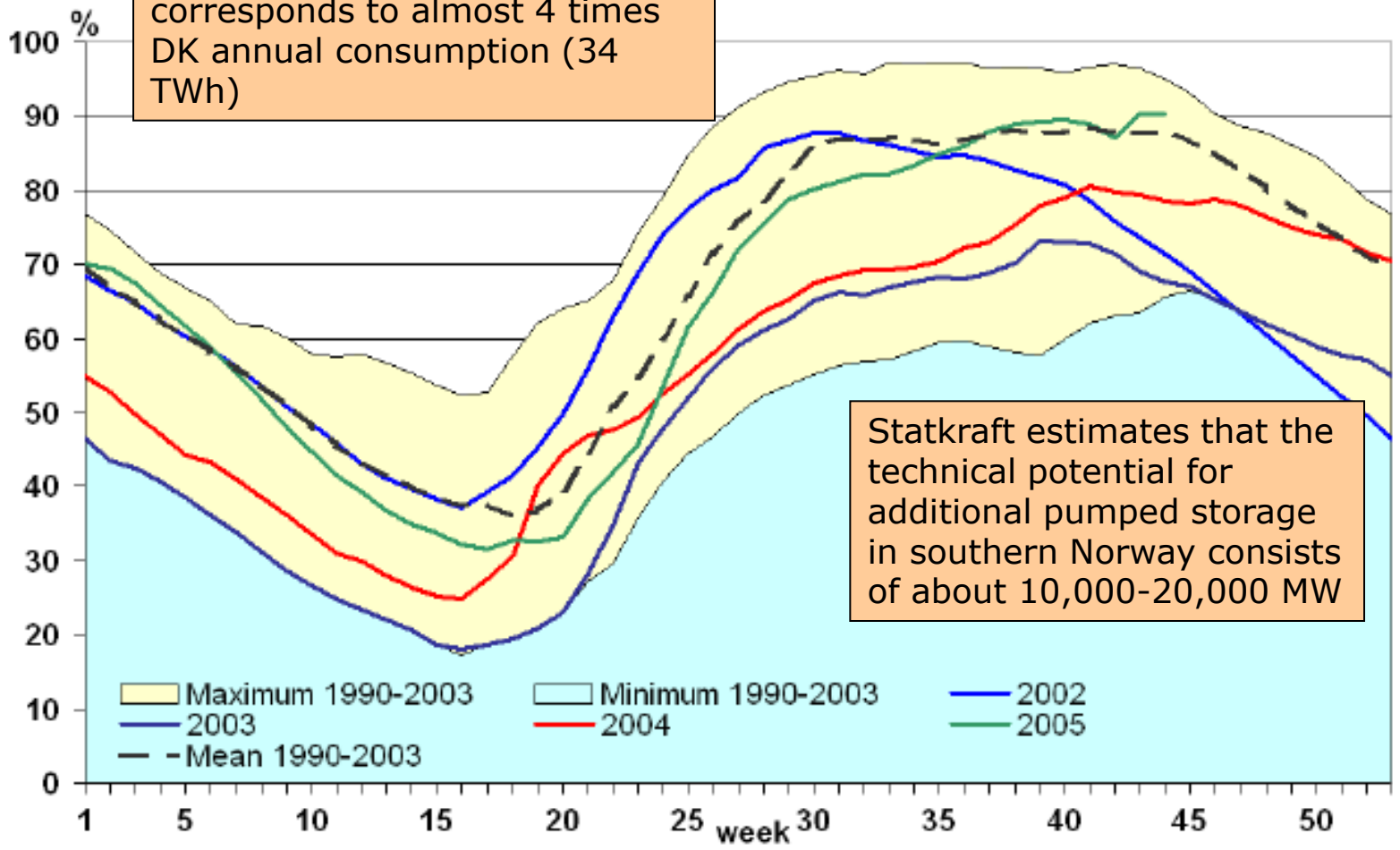
Which options reduce the price and revenue effects

Norwegian reservoir levels and the flexibility provided by hydropower



Norwegian reservoir levels vary but capacity and prospects for pumped hydro large

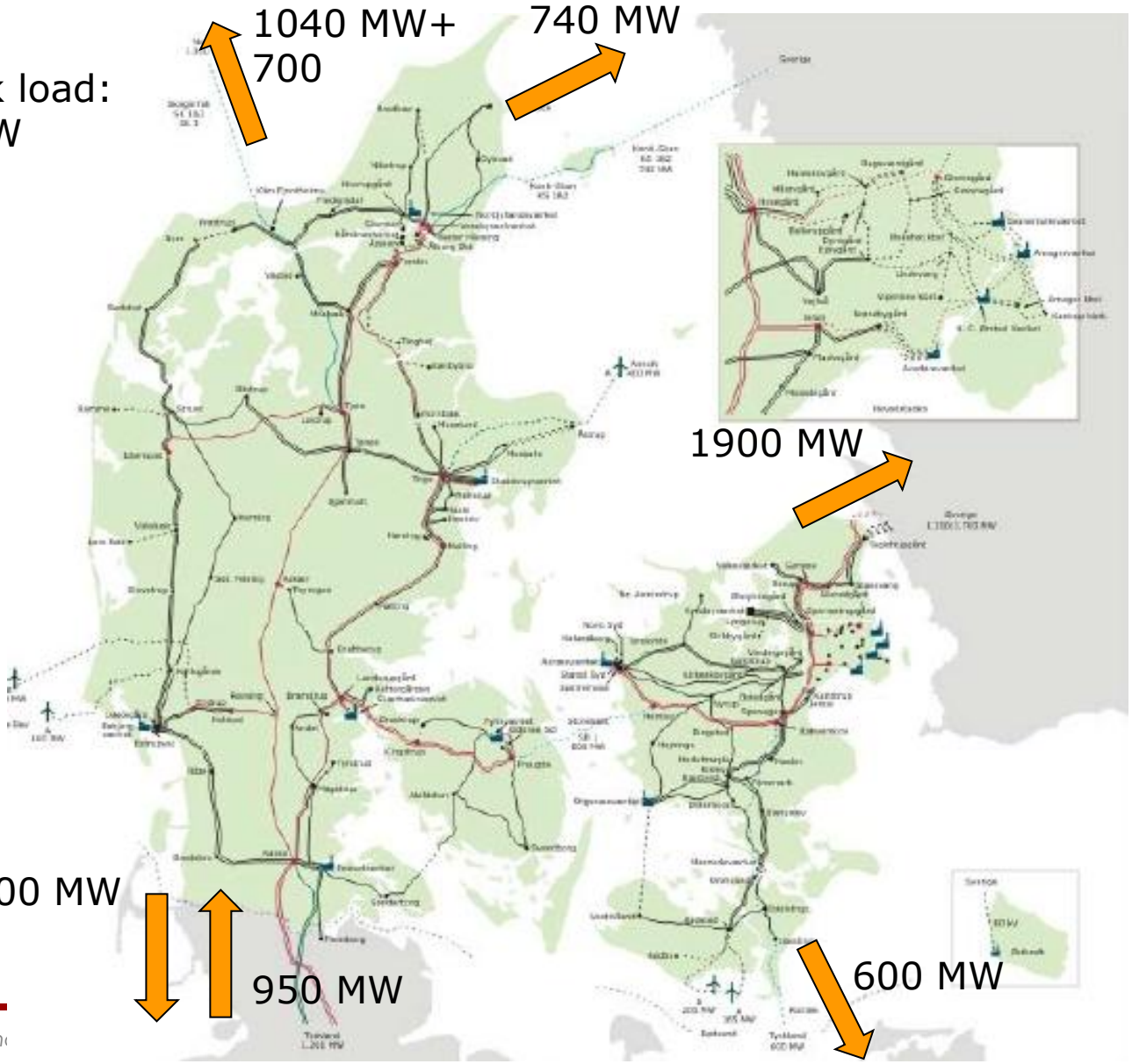
Total hydropower capacity in Norway: approx 124 TWh corresponds to almost 4 times DK annual consumption (34 TWh)



Statkraft estimates that the technical potential for additional pumped storage in southern Norway consists of about 10,000-20,000 MW

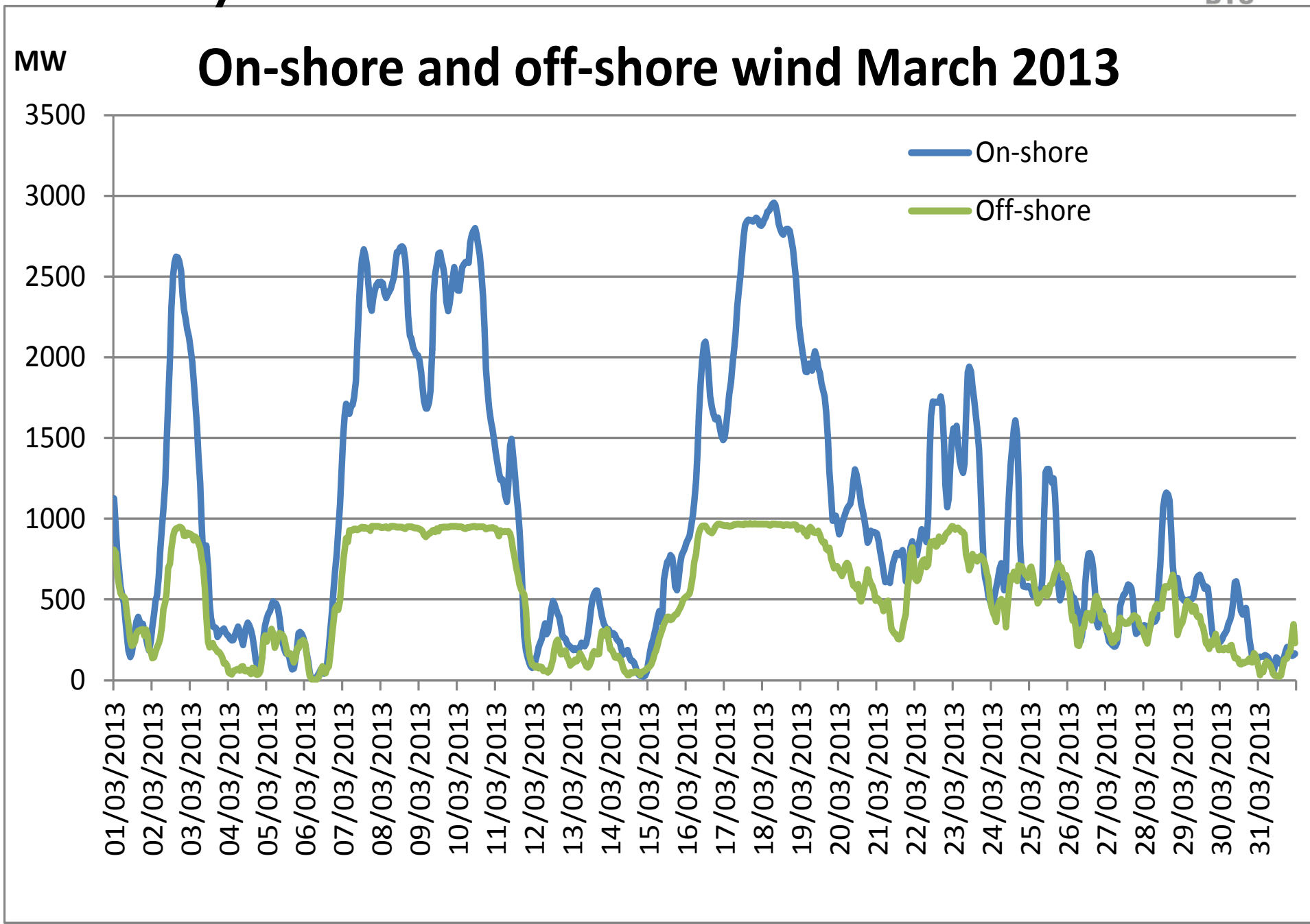
Strong interconnections and additions facilitate use of pumped storage in reservoirs

DK peak load:
6500 MW



Diversify renewable sources and location

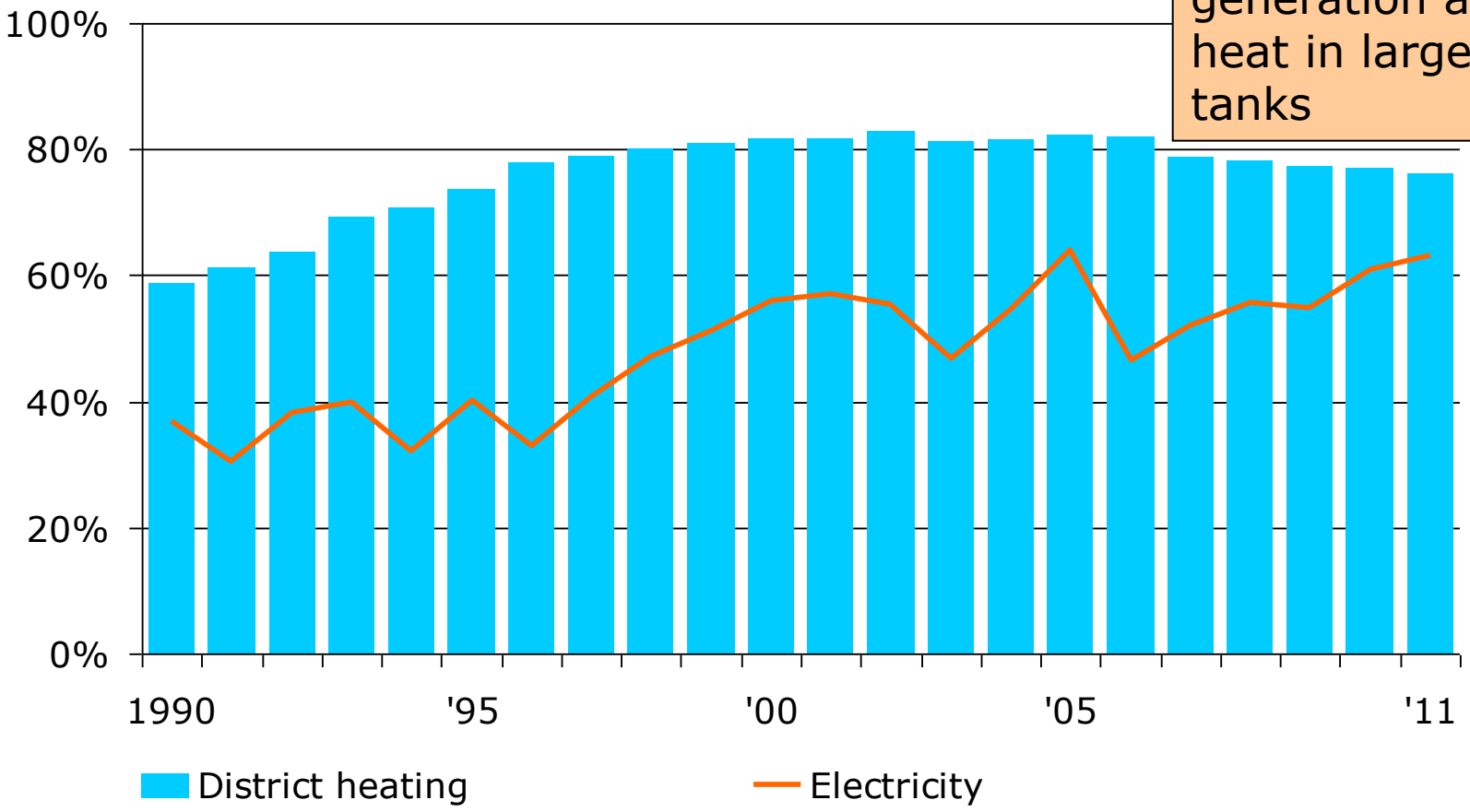
DTU



Danish district heating and heat pumps supply flexibility

Combined Heat and Power (CHP) share of thermal power and district heating production

CHP provide flexibility in case of high wind generation and store heat in large storage tanks



Heat pumps adds flexibility by using electricity when cheap and shutting off when expensive

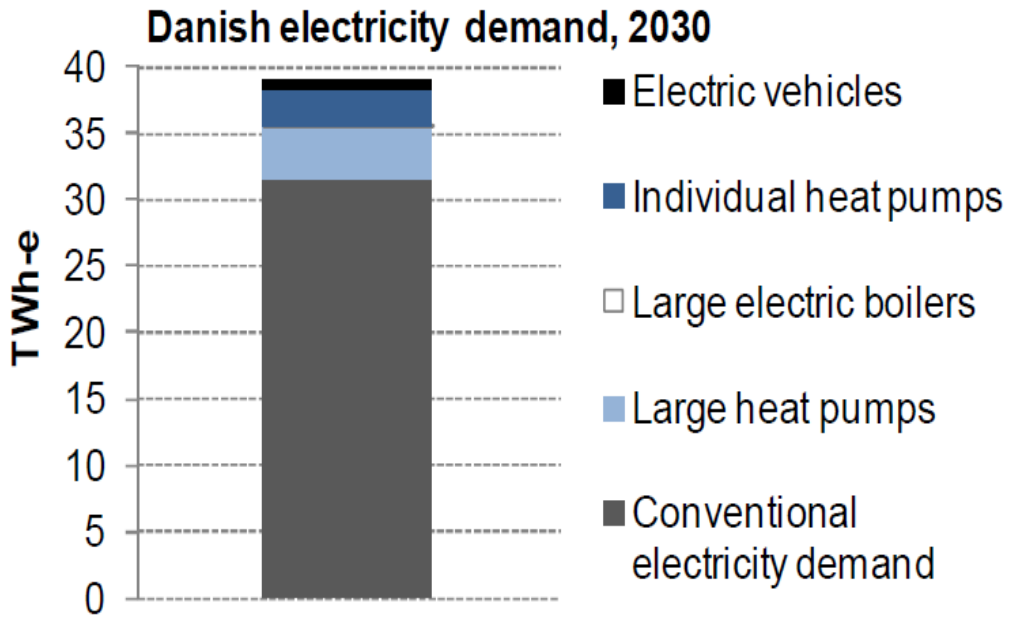


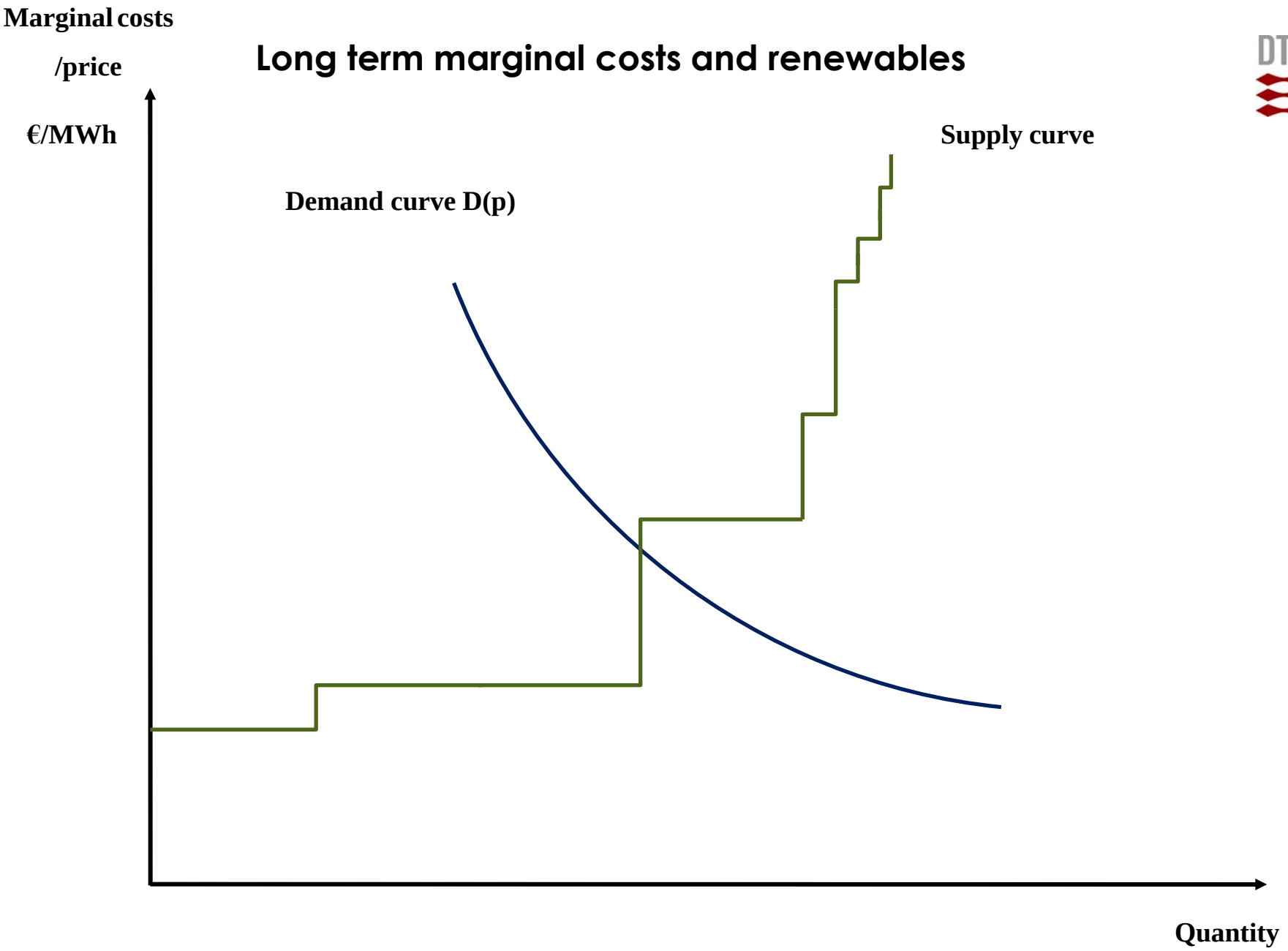
Figure 2. Danish electricity demand in 2030 as expected by Energinet.dk (incl. grid losses) [5].

The long term challenge
How to make investment in conventional technology (back-up/flexibility) profitable with low prices

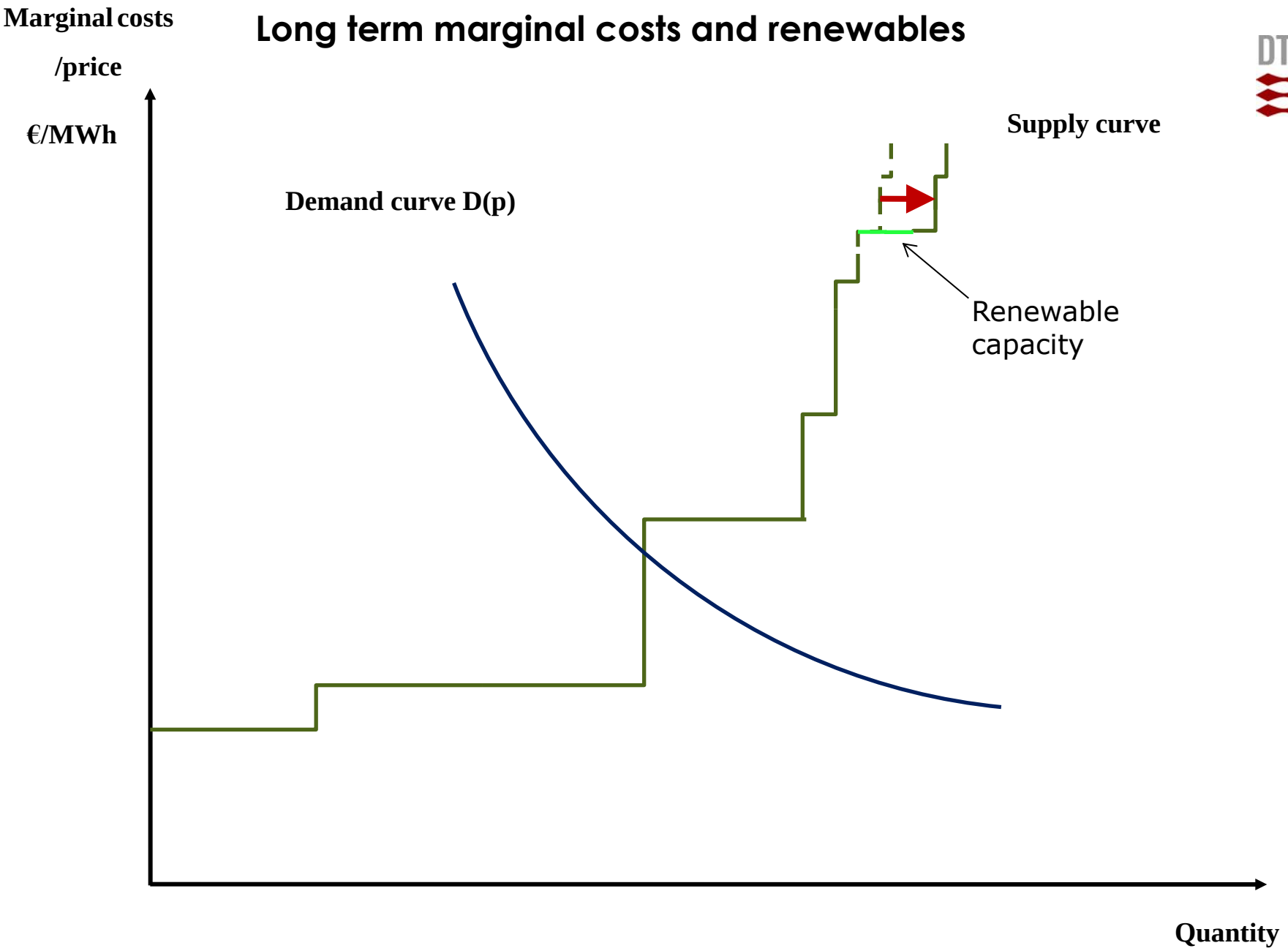
Long term marginal costs

- Intermittent renewable technologies have **low short term** marginal costs *but* **high long term** marginal costs (high investment costs)
- The long term supply curve is only affected at the top end (the top part shift to the right)
- Therefore they require financial support to compete as the preferred investment technology
- The investment in renewables affects the short term power prices downwards
- The investment incentive provided through the short term power markets are thus reduced and
- The conventional capacity will be reduced

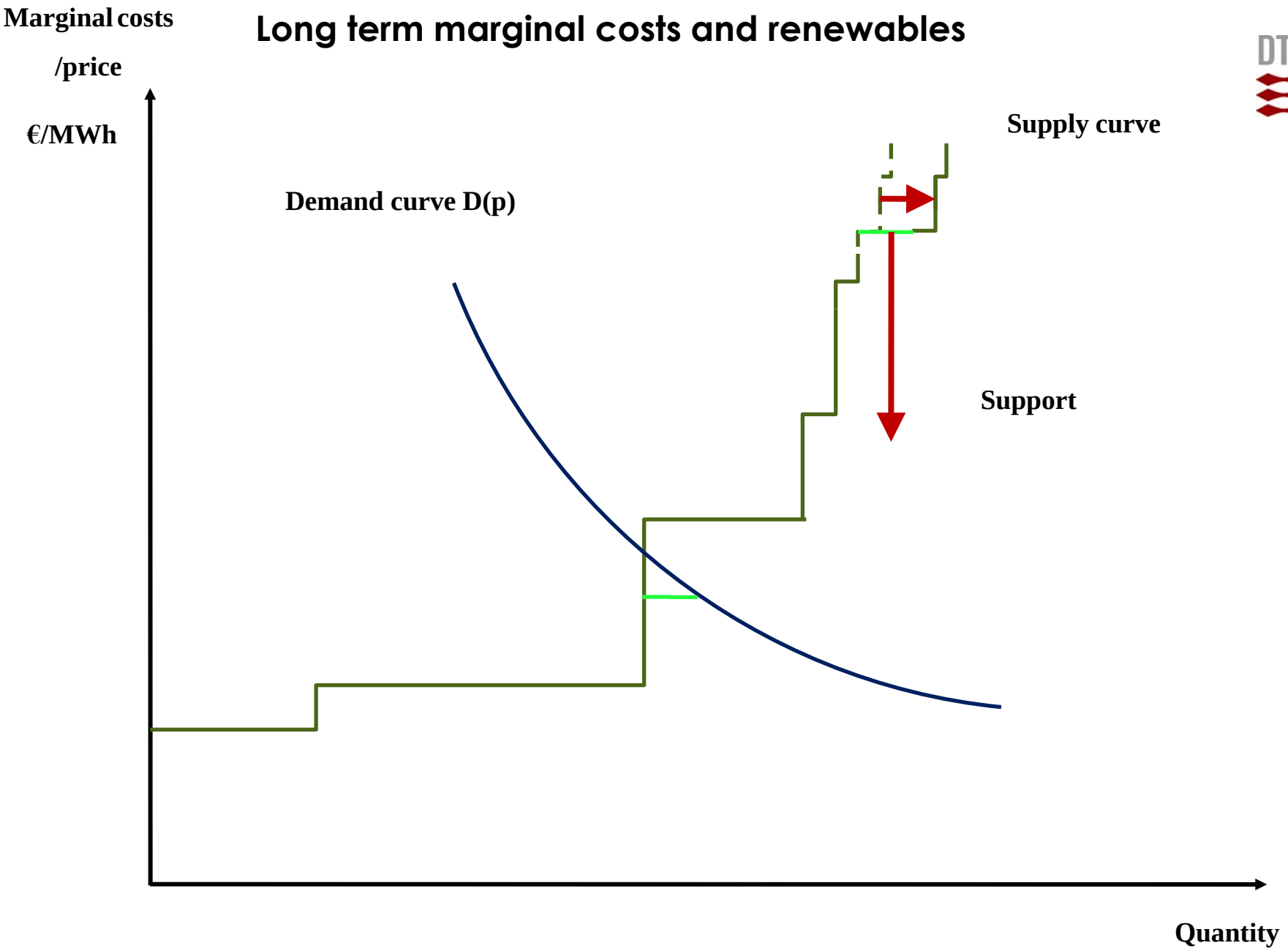
Long term marginal costs and renewables



Long term marginal costs and renewables



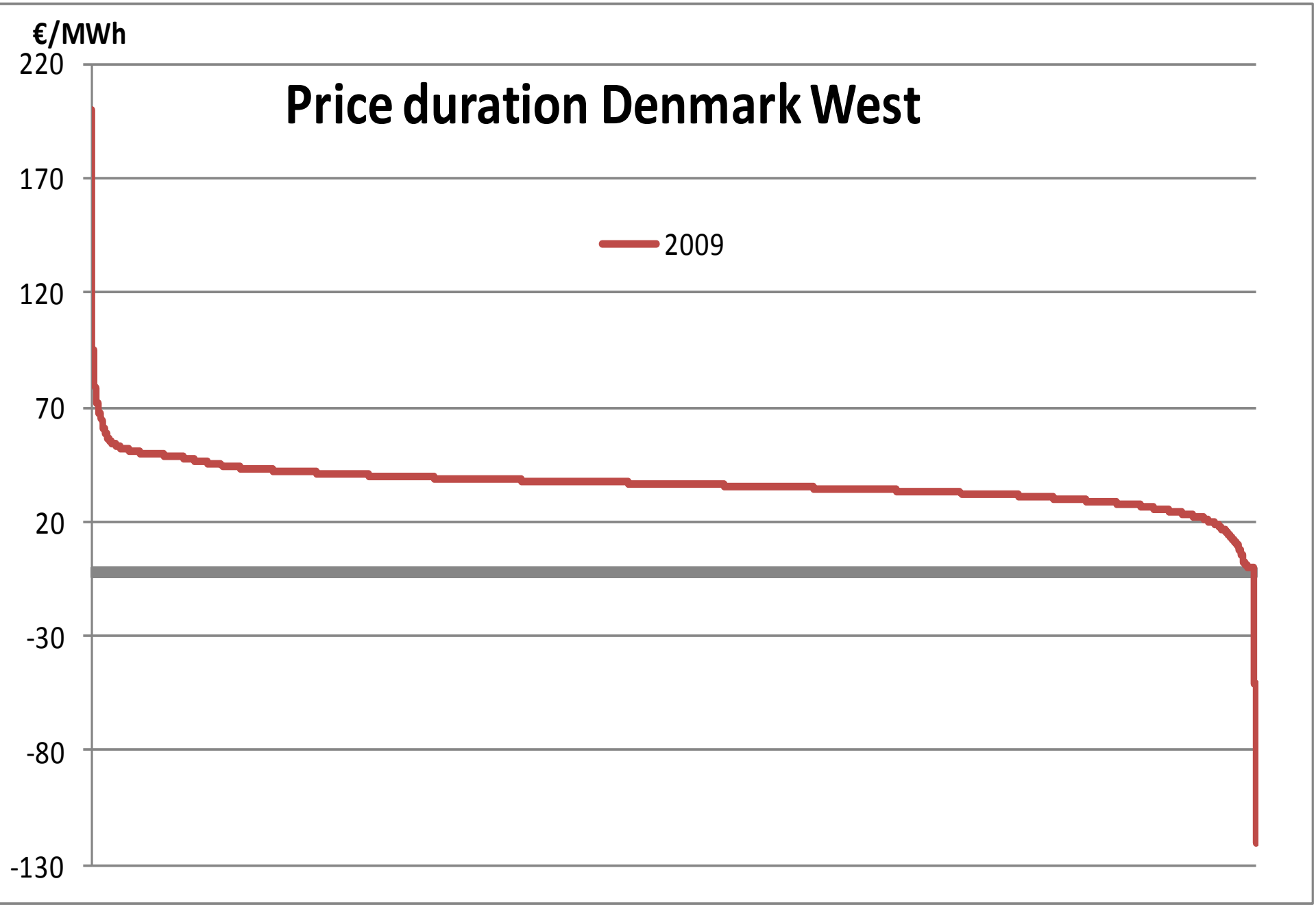
Long term marginal costs and renewables

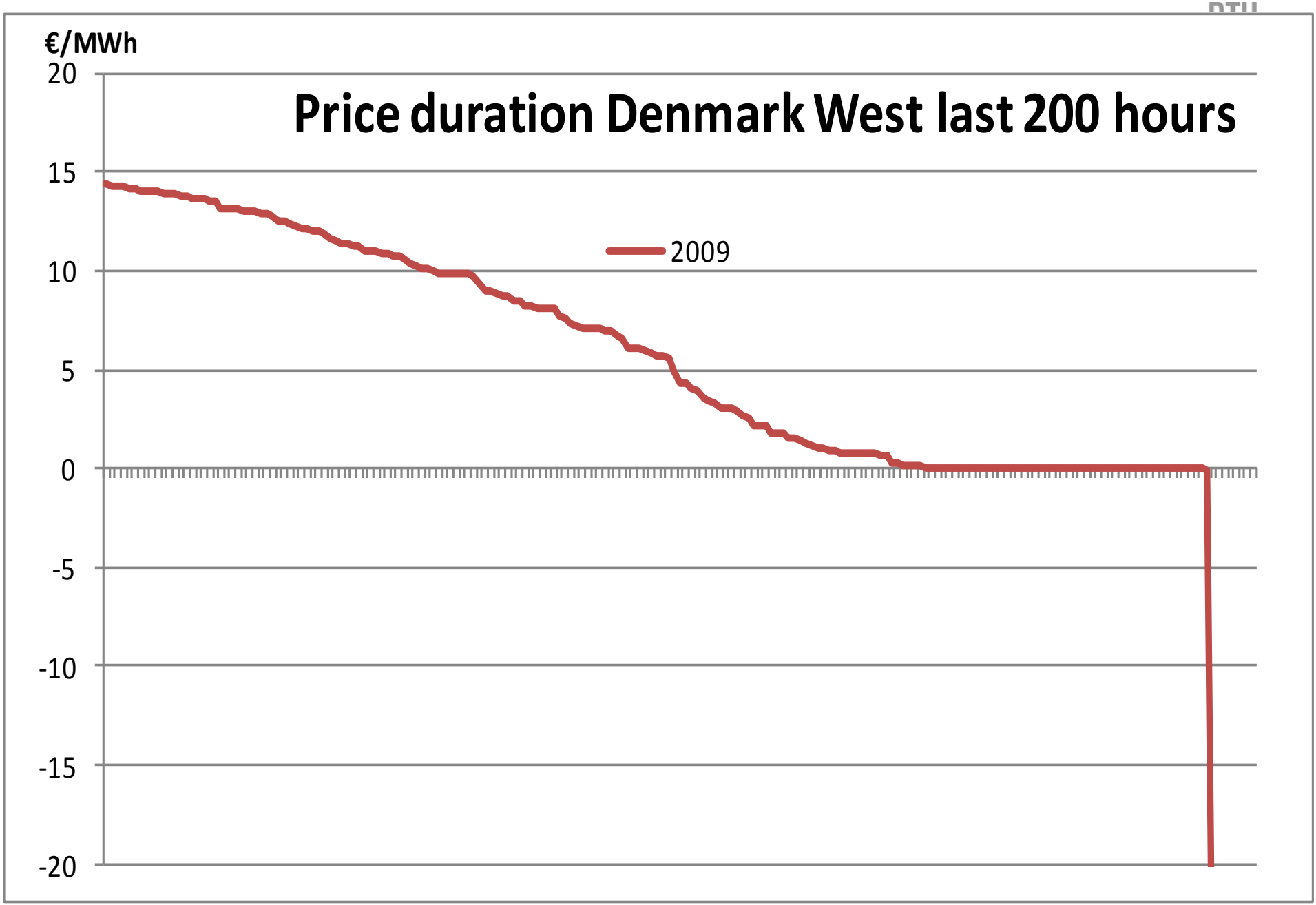


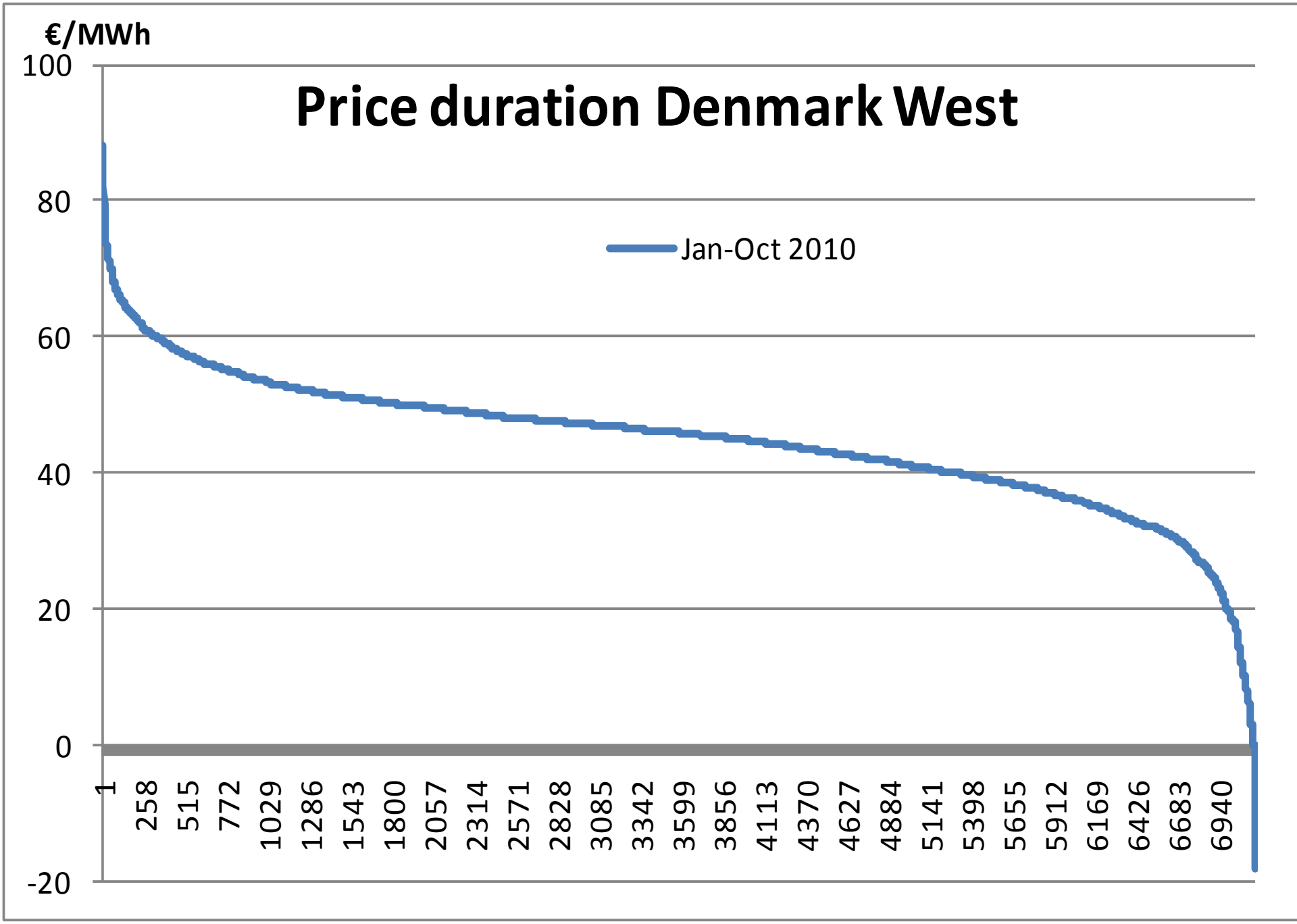
Negative prices?

Negative prices for electricity

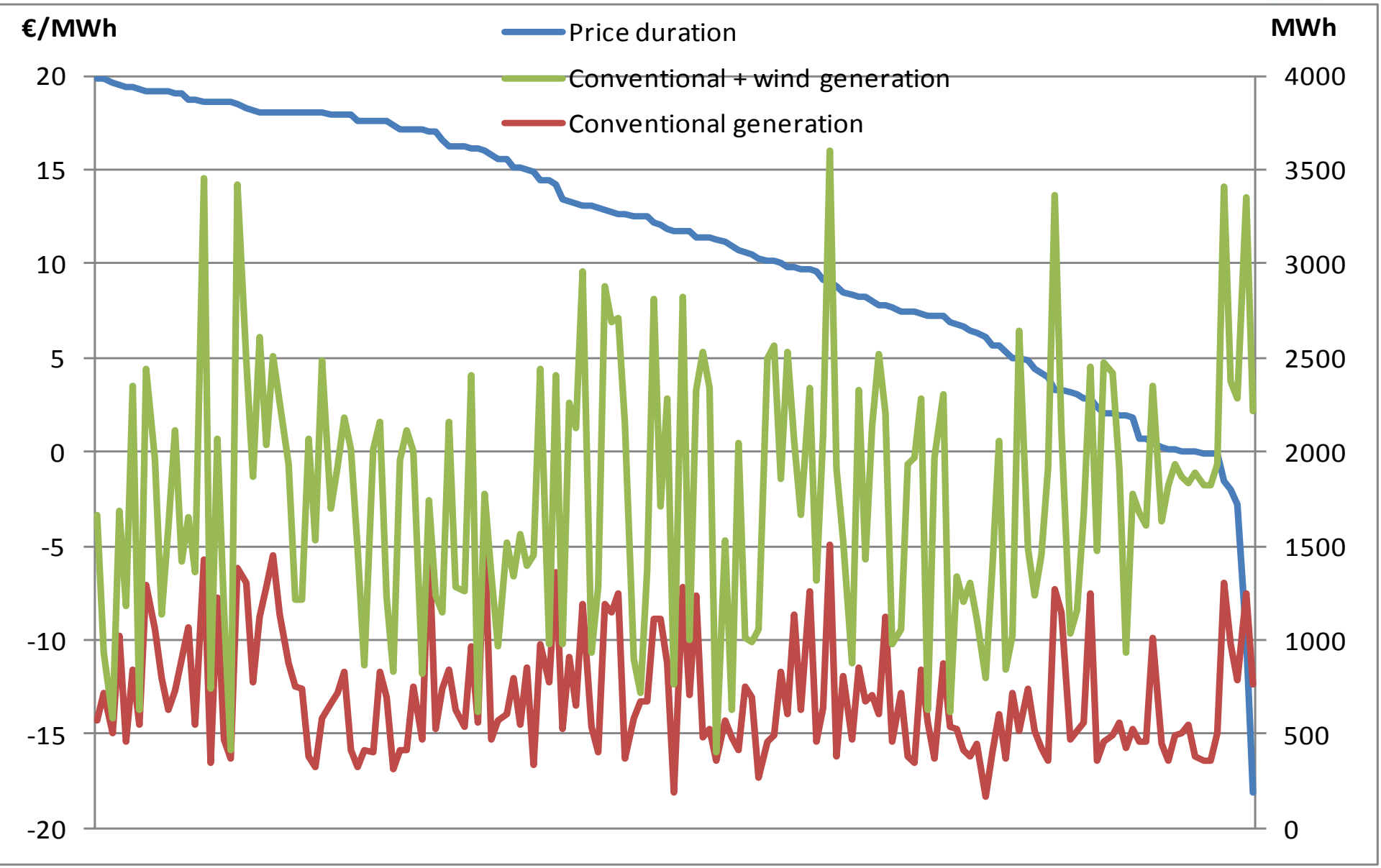
- Does not sound logical
- The marginal value of using more electricity is negative?
- Does not fit with normal assumptions
- There are good explanations for negative prices in power markets
- Important to allow the negative price signals passed to all generators for efficient allocation of production


€/MWh
220
170
120
70
20
-30
-80
-130
Price duration Denmark West
2009

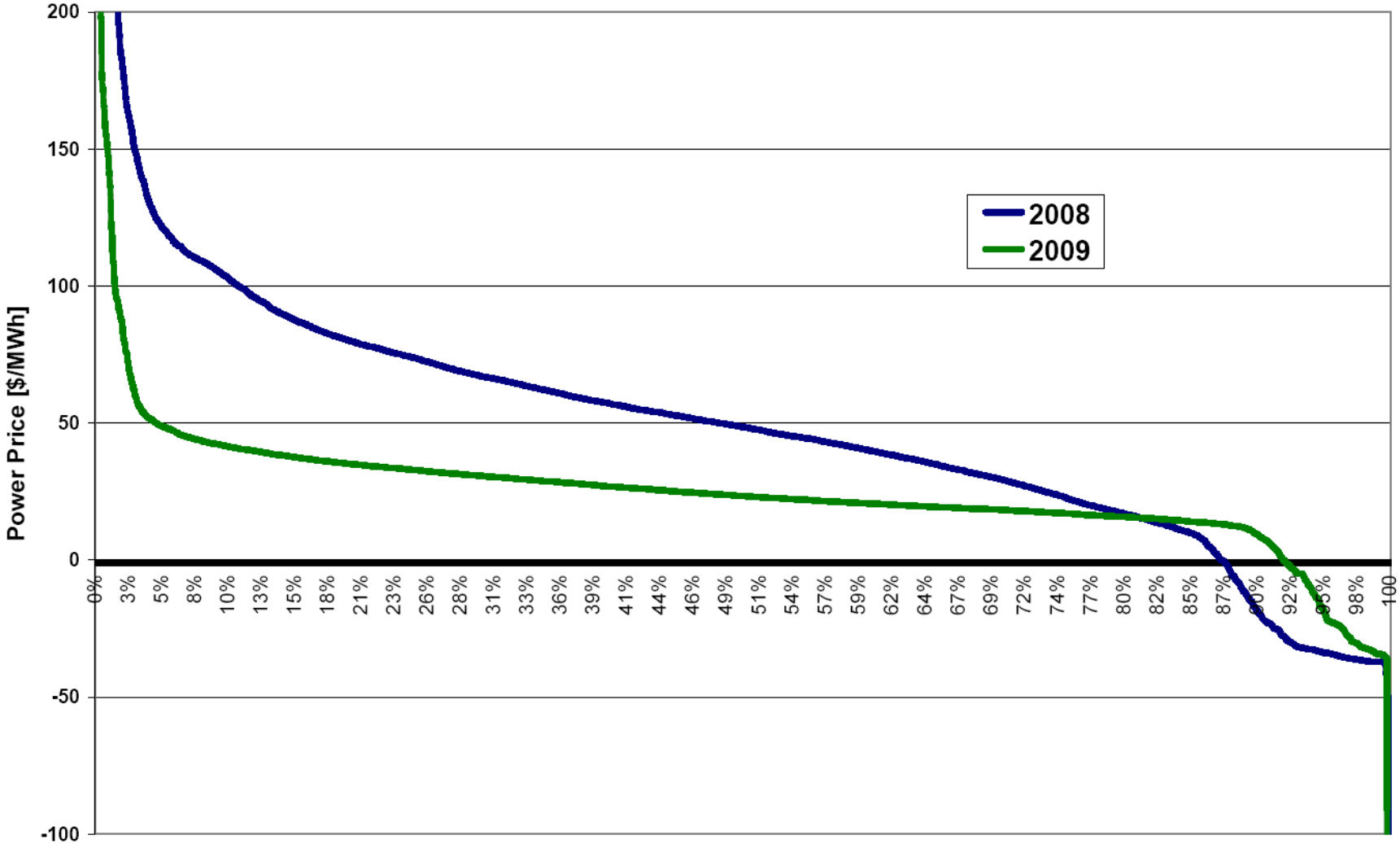

€/MWh
20
15
10
5
0
-5
-10
-15
-20
Price duration Denmark West last 200 hours
2009


€/MWh
Price duration Denmark West
Jan-Oct 2010
100
80
60
40
20
0
-20
1
258
515
772
1029
1286
1543
1800
2057
2314
2571
2828
3085
3342
3599
3856
4113
4370
4627
4884
5141
5398
5655
5912
6169
6426
6683
6940

Price duration 165 hours with lowest prices in 2010



Price duration curves – Texas west

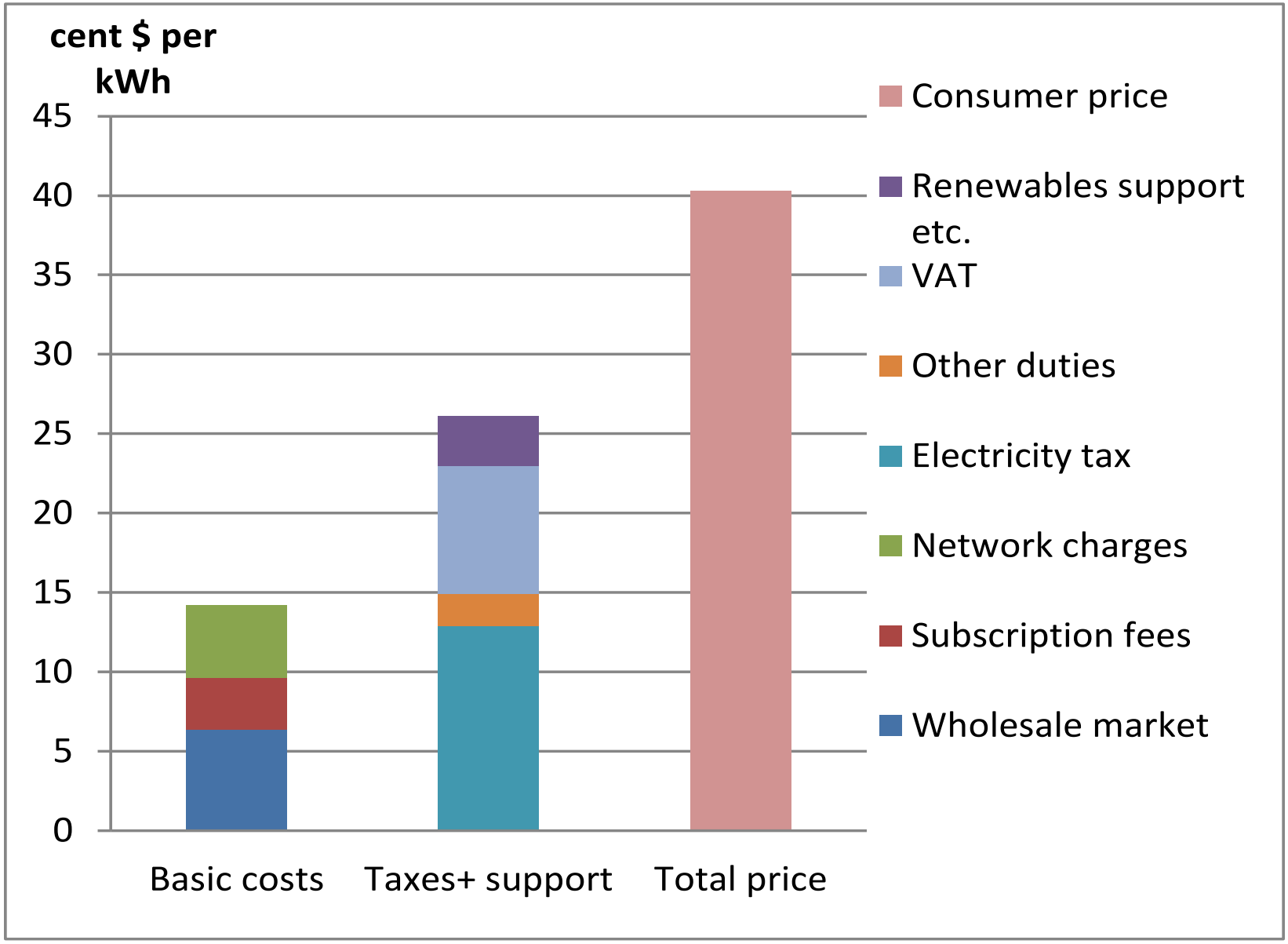


Source: ERCOT (2010)

Negative prices: Explanation and solution

- Stop and start costs for conventional generators (minimum up and down times)
- Renewable generators are subsidised (feed-in tariff or production based tax credits)
- Renewable generation stay online as long as the negative price is less than the support
- Solution:
  - use dynamic tariffs (tax) element of consumer price reduced when zero wholesale price
  - instruct renewables to shut down – involuntarily curtailment
  - reduce/remove the support when power prices are zero or below – voluntary curtailment
- Result: Much less zero and negative prices after a bit of learning

Electricity price for residential consumer in 2013



Thank you for your attention!

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